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Understanding how individuals perceive carbon dioxide

Implications for acceptance of carbon dioxide capture and storage

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Executive summary

Carbon dioxide capture and storage (CCS) presents one potential technological solution for mitigating the atmospheric emission of carbon dioxide sources (GCCSI, 2011; IEA, 2009). However, CCS is a relatively new technology with associated uncertainties and perceived risks. For this reason, a growing body of research now focuses on public perceptions and potential for societal acceptance of CCS technology.

Almost all explanations of CCS technology make reference to carbon dioxide, with an assumption that the general public understands CO_2. It has become apparent that the general public's knowledge and understanding of CO_2's properties influences how they engage with CO_2 emitting industries and CCS technologies (Wallquist, Visschers, & Siegrist, 2009). However, surprisingly little research has investigated public perceptions, knowledge, and understanding of CO_2. This investigation attempts to fill that gap.

This report describes an investigation of how citizens of three countries—Japan, Australia, and the Netherlands—perceive CO_2. Furthermore, it attempts to relate individual perceptions of CO_2 to perceptions of CCS, and to determine how information provision about the underlying properties and characteristics of CO_2 influences individual attitudes towards low carbon energy options, particularly CCS.

In brief, the research had four ultimate aims. It aimed to:

- Explore the **public's knowledge and understanding**[1] of the **properties of CO_2**;
- Examine the **influence of that knowledge** on their **perceptions of CO_2 and CCS**;
- Investigate how **information provision** about the underlying properties and characteristics of CO_2 **influences individual attitudes** towards CCS; and
- Identify if any **differences between countries** exist in relation to values and beliefs, knowledge of CO_2's properties, and CCS perceptions.

The research employed both qualitative and quantitative methods designed to complement each other. The qualitative component consisted of interviews and focus groups aimed at exploring public knowledge of CO_2 across each of the countries. They also provided an opportunity to explore how participants reacted when provided with information about CO_2 and CCS. Using a grounded theory approach, common themes and attributes identified in the qualitative component informed the development of a large scale survey, which was piloted and then rolled out in each country.

Results from the interviews and focus groups revealed that respondents had limited knowledge of CO_2. Although respondents were aware of the gas, and many understood basic facts about CO_2 such as that plants absorb it and burning fossil fuels produces it, the majority found it difficult to describe the specific characteristics or properties of CO_2. Respondents from focus groups tended to perceive CO_2 negatively as toxic and harmful. Common misperceptions shared by survey respondents included the belief that CO_2 had qualities similar to air pollution or soot, and that it

[1] The terms "knowledge" and "understanding" are for the most part used interchangeably throughout this report.

was flammable or explosive. Substantial uncertainty existed over whether CO_2 affects humans in the same way as carbon monoxide. Few respondents could describe uses for CO_2. Likewise, many research participants had misperceptions regarding the mechanism of climate change: these participants believed that CO_2 emissions caused ozone depletion, thereby leading to climate change. This confirms the results of earlier research in Australia, conducted during October 2010, in which 59% of Australian respondents believed that "the hole in the ozone layer contributes to climate change" (Ashworth, Jeanneret, Gardner, & Shaw, 2011).

Awareness of CCS was generally low, with greater awareness among residents of the Netherlands than of Japan or Australia. This may relate to substantial media attention to the Barendrecht CCS project between 2008 and 2010 (Feenstra et al., 2010). Perceptions of CCS also varied between each country. After the presentation of basic information on the technology during interviews and focus groups, Japanese respondents tended to regard CCS favourably, whereas the majority in Australia regarded CCS negatively, while perceptions were mixed in the Netherlands. Overall, respondents from the focus groups and interviews did not tend to support implementing CCS near their homes. Survey respondents were generally more favourable to offshore rather than onshore storage while the differences in extent of opposition between onshore and offshore vary among three countries (in Japan it was smallest[2]). More broadly, participants from all three countries tended to agree that to a certain extent, society should accept some risks in relation to new technologies; and also tended to be averse to paying additional tax to address climate change.

The information about CO_2 provided in the interviews, focus groups, and surveys promoted greater understanding and to a certain extent dispelled previous misperceptions held by some respondents, but it did not dramatically change perceptions and opinions on CCS. Importantly, survey results showed that information on natural phenomena involving CO_2[3], and on CO_2's behaviour in CCS, had a weak but significant negative effect on CCS perceptions, whereas information on CO_2's properties and chemistry had a positive effect. Furthermore, interview participants considered descriptions of CO_2's behaviour in CCS and its natural patterns of occurrence to be important, even though such information did not dramatically change their perceptions and opinions. Almost all misperceptions about CO_2 correlated with misperceptions about CCS.

These findings highlight the importance of providing basic and wide-ranging information on CO_2 as part of CCS communications. In addition, the variety of respondent reactions signals the value of addressing this variation in beliefs throughout future communication efforts.

One interesting result from this research was the strong relationship between participants' tendency to believe in the credibility of certain information and communication sources and their knowledge of CCS topics. Trust in national NGOs, local NGOs, friends, and the internet—as opposed to public sector organisations, local government, national newspapers, and scientists—was negatively correlated with correct understanding of CCS. This has serious implications for CCS communications, as it suggests that the same members of the public who are less likely to trust public sector and scientific sources may also be the people with the poorest understanding of CCS.

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[2] In the previous study in Japan, there was a similar result about support for offshore /onshore in a questionnaire survey (Mizuho Information & Research Institute 2010). In the same study, it was found that respondents raised spatial contiguity as the main reason for the support of offshore storage over onshore storage in focus groups (Mizuho Information & Research Institute 2010). We would interpret it would be one of the reasons for the small difference in support between offshore and onshore that a large part of Japanese population resided sea coast areas.

[3] "Natural phenomena involving CO_2 "originally means analogical phenomena of CCS involving CO2 The information sheets includes, natural 'CO2 leakage events', natural or accidental human exposure to higher concentration CO2 and natural CO2 reservoir.

Recommendations derived from this work may be summarised as follows:

- ***Efforts to promote dialog and understanding about CCS should incorporate information on CO_2's properties and chemistry.*** Research found a limited knowledge base among respondents. In the absence of such knowledge, members of the public may be unclear on how to perceive CO_2, and may subscribe to a variety of mistaken beliefs.

- ***Balanced and complete information on CO_2's properties should be made available.*** When communicating this information, it is important to include CO_2's effects on humans and the environment (e.g., potential for soot-like effects and toxicity). Information regarding CO_2's scientific and chemical properties was shown to have a weak but significant positive effect on CCS perceptions.

- ***Topics deemed important by respondents should be addressed by communicators.*** The variation of reactions, anxieties, and beliefs amongst respondents highlighted the importance of accounting for these in communication and education efforts regarding CO_2 and CCS. Any effort to engage in dialogue with the public regarding CCS should be based on an inventory and understanding of public levels of knowledge and information needs. This information can be collected through a baseline survey, as described in the *Communication/Engagement toolkit for CCS projects* (Ashworth et al. 2011a).

- ***Care should be taken in describing CO_2 natural phenomena.*** It is important to present open and transparent information, such as on incidents during which naturally-occurring CO_2 has harmed people, plants, and animals (i.e., the Lake Nyos[4] and Mount Mammoth[5] events). Information on natural phenomena involving CO_2 had a weak but significant negative effect on CCS perceptions, suggesting that people use these descriptions of natural phenomena to make inferences about CCS, CO_2 and its effects.

- ***Care should be taken in describing the behaviour of CO_2 in the CCS process.*** Conveying correct and complete information on CO_2's behaviour is important because this understanding will be helpful to mitigate misunderstandings that can arise when respondents receive incomplete or indirect information about CCS.

- ***Many members of the public still require basic information on climate change, CCS, and their relationship to CO_2 emissions.*** Awareness of these topics does not directly imply knowledge, as for example, more participants indicated having heard of CCS than did actually understanding what it is.

- ***Additional CCS education and outreach campaigns should be planned through less-formal mechanisms.*** Given that the correlation between trust in informal sources and poorer understanding of CCS, sole reliance on the formal information and communication sources (i.e., public sector organisations, local government, national newspapers, and scientists) may not reach the people with the poorest understanding of CCS, who instead place their trust in NGOs, friends, and the internet.

[4] In 1986, naturally-occurring CO_2 was released from Lake Nyos in Cameroon, killing animals and 1,700 people.

[5] At the Mount Mammoth volcano in the United States, a large volume of CO_2 seeping from underground has been killing trees.

Part I Introduction

1 Introduction

Climate change has often been described as a “wicked”, diabolical problem (Stern, 2006; Lorenzoni, Jones, & Turnpenny, 2007), with most governments working to find solutions to reduce overall global carbon emissions (United Nations Framework on the Convention on Climate Change, 1998). For some countries, particularly that rely heavily on fossil fuels, CO_2 capture and storage (CCS) presents a potential technological solution for mitigating CO_2 sources (GCCSI, 2011; IEA, 2009). However, as demonstrated on several occasions, the successful adoption of CCS technology will depend partly on its societal acceptance, which in turn depends on how it is ultimately understood by citizens and communities.

Recent research has shown that public knowledge and understanding of CO_2 affects public engagement with CCS technologies (Wallquist, Visschers, & Siegrist, 2009). Previous focus groups by Itaoka and colleagues (2007) found that some laypeople have only a vague knowledge of CO_2’s properties. Itaoka and colleagues also found that providing information on possible human health effects, along with information on the low possibility of accidents—or on a few natural cases, such as the Lake Nyos incident—surprises the public and typically leads them to classify CCS as very dangerous (2009). Overall, research has found that erroneous beliefs about CO_2 may hinder efforts to provide factual information on CO_2 mitigation technologies (Wallquist, Visschers, & Siegrist, 2009).

A lot of communication about global warming and energy transition seems to lack explanation of CO2 itself though. For instance a media analysis of Dutch newspaper articles relating to CCS from early 2009 to end of 2011 showed that only a minute percentage of articles explained what CO_2 is or how it relates to global warming (Paukovic, Brunsting, & De Best-Waldhober, 2011). Yet for communication to be effective, it is essential that communicated information fits the knowledge level of the communicators. If most lay people do not know about CO_2, but the level of communication does assume such knowledge, this gap is bound to generate a lot of misunderstanding.

This international research project conducted across Australia, the Netherlands, and Japan aims to address that gap. It explores the public’s knowledge and understanding of CO_2’s properties, and also examines the influence of that knowledge on the public’s perception of CO_2 and CCS. As a secondary objective, it investigates how information provision about the underlying properties and characteristics of CO_2 influence individual attitudes towards CCS.

2 Literature review

2.1 Perceptions and understandings of climate change

Given the increasing international interest in climate change, multiple studies have been conducted to explore how climate change is perceived and understood (Berk & Schulman, 1995; Bord, Fisher, & O'Connor, 1998; Bostrom, Morgan, Fischhoff, & Read, 1994; Lorenzoni & Pidgeon, 2006; Patchen, 2010; Weber, 2010; Weber & Stern, 2011). Researchers focused on understanding perceptions of the range of low carbon energy solutions have also tended to investigate attitudes towards climate change. This is because early research has found that when reducing carbon emissions is seen as unnecessary, support for investment in low carbon energy options rapidly wanes (Ashworth, Carr-Cornish, Boughen, & Thambimuthu, 2009; Bradbury, et al., 2009; Shackley, Gough, & McLachlan, 2005).

Results of research on public perceptions and understanding of climate change vary and are usually highly dependent on context. For example, timing of the investigation, particularly with respect to a country's current weather patterns and current political approach to climate change, typically influences how individuals respond to certain questions on their beliefs and experiences of a changing climate (Ashworth, Jeanneret, Gardner, & Shaw, 2011; Reser, et al., 2011). Even the framing of questions will influence how participants choose to respond (Reser, et al., 2011).

Although general awareness of climate change has increased over the past two decades, individuals' understandings of the topic remain incomplete (Read, Bostrom, Morgan, Fischhoff, & Smuts, 1994; Reynolds, Bostrom, Read, & Morgan, 2010). Despite increased popular media attention and some government policy focus on climate change and global warming, members of the general public still tend to conflate ozone layer depletion and global warming issues, and display uncertainty about the relationship between anthropogenic global warming and rising atmospheric CO_2 levels (Reynolds, et al., 2010; Stamm, Clark, & Eblacas, 2000; Whitmarsh, Seyfang, & O'Neill, 2011). Some would argue that belief in climate change has actually declined. This is particularly evident in polls that were conducted around the time of 'Climategate' in 2009, when internal communications between climate scientists became public and appeared to demonstrate that the scientists were conspiring to present a stronger case for climate change than was actually substantiated (Paukovic et al., 2011). During this time, the integrity of Intergovernmental Panel on Climate Change (IPCC) research findings in the 4th Assessment Report was questioned (Leiserowitz, Maibach, Roser-Renouf, Smith, & Dawson, in press).

Our research team has previously found that while most Australians believe that the climate is changing, a small proportion of the general public are either unsure (15%) or remain sceptical (7%) about climate change and its causes (Ashworth, et al., 2011b). Similarly, the majority of the general public in Japan are convinced that climate change is happening, while about 10 percent remains to some extent sceptical (Mizuho Information & Research Institute 2010). In the Netherlands, the majority of the general public still believed in 2010 that temperatures will increase in the future, but this number has decreased significantly in the last years, which coincides with the timing of Climategate (Paukovic et al., 2011). The data in this study was not suitable to prove a causal relationship though. Only a very slight majority of people believe that anthropogenic emissions lead to global warming.

2.2 Perceptions of CO_2

Very little existing research literature describes the general public's perceptions of CO_2. Research into public understanding and perceptions of climate change and energy technologies have only examined individual knowledge and perceptions of CO_2 as a secondary focus, if at all. However, these studies have demonstrated that substantial gaps exist in the general public's knowledge and understanding of CO_2. For example, interviews conducted by Wallquist, Visschers, and colleagues (2009) demonstrated a lack of knowledge on the physical-chemical properties of CO_2 among the 'lay' (i.e. non-scientific) population. Misconceptions were particularly evident with regards to dispersion rates of CO_2 in the atmosphere and its density in a super-critical state and in solution (Wallquist, et al., 2009).

In addition to CO_2's chemical properties, its sources and the environmental problems it causes also remain a source of confusion for members of the general public (Curry, Reiner, Ansolabehere, & Herzog, 2005; Sharp, Jaccard, & Keith, 2009). An early cross-national public opinion study using surveys delivered in the USA, UK, Sweden and Japan found that respondents had difficulty associating CO_2 with global warming as opposed to other environmental problems, such as ozone depletion (Reiner, et al., 2006b). However, when asked to identify the sources and sinks of CO_2, the majority of respondents in all countries correctly identified cars, coal-fired power plants, and home heating as causes for increasing levels of CO_2. Likewise, almost all of the respondents understood the underpinnings of photosynthesis in plants, correctly responding that trees could be a sink to reduce atmospheric CO_2 levels. In a replication of that survey in Australia and the UK in 2006, the results were almost identical (Ashworth, Reiner, Gardner, & Littleboy, 2007).

Many laypeople are unfamiliar with the mechanisms by which climate change takes place. In their online survey of the Australian public, Ashworth, Jeanneret and colleagues (2011b) found that half of respondents incorrectly identified ozone depletion as a cause of climate change; and only just over half understood the mechanism of the greenhouse effect. Similarly, de Best-Waldhober, Daamen and colleagues (2009) found that the majority of respondents in the Netherlands were unable to identify the relationship between fossil fuel use, CO_2, and global warming.

Even today, laypeople commonly misperceive and misunderstand CO_2. A recent study of the Dutch general public by Paukovic and colleagues (2011), which measured CO_2 knowledge, suggests that incorrect beliefs and uncertainty about the properties of CO_2 are still prevalent. For example, 25.2% of respondents thought or were convinced that people do not exhale CO_2; and 22.4% were unsure about the validity of this claim. Similarly 20.7% thought that CO_2 causes cancer, and 38.4% were unsure whether this was the case or not.

Likewise, recent survey research conducted in the UK by Whitmarsh, Seyfang and colleagues (2011) suggests that knowledge about "carbon" is still limited, even while the causes of climate change are increasingly recognised. The UK survey found that carbon was most commonly conceptualised as meaning 'CO_2'; consequently, it was perceived negatively as harmful, toxic, and an anthropogenic source of climate change, rather than a naturally occurring and abundant building block of life (Whitmarsh, et al., 2011).

These varying misperceptions about CO_2 and associated concepts such as carbon have follow-on effects for peoples' understanding and perceptions of the mitigation techniques (such as CCS) required to address the problems associated with greenhouse gas (GHG) emissions.

2.3 Perceptions of CCS

CCS has the potential to reduce GHG emissions and stem anthropogenic climate change through the mitigation of large amounts of CO_2 (Ashworth, Boughen, Mayhew, & Millar, 2009a; Ashworth, et al., 2009b). While media coverage of CCS has generally increased and become more positive (Hansson & Bryngelsson, 2009), studies from Australia (Ashworth, et al., 2009a), Canada (Sharp, et al., 2009), France (Ha-Duong, Nadaï, & Campos, 2009), Germany (Fischedick, et al., 2009), Japan (Itaoka, et al., 2009; Itaoka, Saito, & Akai, 2005), the Netherlands (de Best-Waldhober, et al., 2009; de Coninck & Huijts, 2005), the UK (Reiner, et al., 2006a), the US (Curry, et al., 2005; Palmgren, et al., 2005; Reiner, et al., 2006b), and Sweden (Reiner, et al., 2006a) all indicate that the general public in these countries has low levels of knowledge about both CCS as a technology (particularly compared with other emission reducing technologies such as wind and solar power – see e.g. Duan, 2010) and the environmental concerns it addresses.

Despite the public's unfamiliarity with CCS as a GHG mitigation technology, a vast body of literature exists that explores how it is perceived by the public. CCS is often perceived negatively as dangerous and risky in several ways, such as: safety; potential for contamination of and damage to the natural environment (i.e. ground water, plants, animals etc.) owing to potential leakage at storage sites; cost; potential to hinder development of renewable energy technologies; and lack of effective contribution to addressing future climate change needs and energy requirement solutions (Ashworth, et al., 2009a; de Best-Waldhober, et al., 2011; Oltra, Sala, Solà, Di Masso, & Rowe, 2010). These perceived risks have, in some instances, led to the rejection of CCS as a mitigation strategy by the general public (Oltra, et al., 2010).

Lack of knowledge about CCS technology and its potential benefits is often cited as a key reason for these negative public perceptions. Several researchers (Duan, 2010; Itaoka, et al., 2005) have suggested that increased support could be garnered for the technology if the public were more fully informed about CCS's potential effectiveness as a GHG mitigation option. Results from Itaoka and colleagues (2009) results support this claim, suggesting that people who claim to have more knowledge about CCS's effectiveness as a climate change mitigation option perceive it more favorably.

Research into CCS perceptions has provided valuable insight into the social factors that influence these perceptions as well as its acceptability as a viable mitigation option. A study conducted by Bradbury and colleagues (2009) demonstrated that participant concerns regarding fairness and trust were key determinants of perceptions of CCS technology in the communities and regions studied. Trust held in sources of information about CCS technology has also been found by others to influence perceptions (Terwel, Harinck, Ellemers, Daamen, & de Best-Waldhober, 2009; Tokushige, Akimoto, & Tomoda, 2007), as have various other factors:

- understanding of CCS's potential benefits and effectiveness (Itaoka, et al., 2005; Terwel, et al., 2009; Tokushige, et al., 2007; Ashworth, et al., 2011b);
- concerns over safety and leakage risks (Itaoka, et al., 2005; Ashworth, et al., 2011b);
- beliefs about who is responsible for CO_2 mitigation action (Itaoka, et al., 2005; Ashworth, et al., 2011b);
- beliefs that employing CCS technology will be detrimental to the development of future renewable energy technologies (Itaoka, et al., 2005; Ashworth, et al., 2011b);

- perceptions about the nature and severity of climate change, and related, whether and to what extent CO_2 mitigation is required (Shackley, et al., 2005; Ashworth, et al., 2011b);
- existing low socioeconomic status; desire for compensation and community benefits; and past experience with government (Ray et. al., 2009; Ashworth, et al., 2011b).

Despite this extensive body of work considering the factors that influence the general public's perceptions of CCS, no current research exists that effectively, and specifically, explores the influence of knowledge about CO_2 on perceptions of CO_2 and perceptions of CCS as a mitigation technology.

2.4 Links between knowledge of CO_2 and perceptions of CCS

Some existing research does make a limited exploration of the relationship between CO_2 knowledge and perceptions of CCS. In a recent study by Paukovic and colleagues (2011), higher survey scores relating to overall knowledge of CO_2 were positively related to attitudes towards CCS.

Wallquist, Visschers and colleagues (2010) also touched on this topic in their investigation of the influence of knowledge (including knowledge of CO_2) and misconceptions on risk and benefit perceptions of CCS. They found that "knowledge of CO_2 and storage mechanisms decreased risk perception" of CCS technology. However, they go on to conclude that since their respondents had a limited understanding of CO_2 and subsurface conditions, "more knowledge about CO_2 might ease people's concerns about the risks of CCS but at the same time lead to less confidence in its benefits" (Wallquist, et al., 2010, p. 6561).

While such work provides insight into the link between knowledge of CO_2, and perceptions of CO_2 and of CCS, no specific research has been conducted solely to explore this relationship. The project described in this report addresses this apparent gap in understanding.

Part II Methods

3 Overview

This research project's larger goal was to understand how knowledge and understanding of CO_2 influences attitudes towards CCS. A secondary aim was to investigate how providing information using an experimental survey mechanism affects respondents' perceptions. To meet these goals while maximising validity (Creswell, 2002; Tashakkori & Teddlie, 1998), a mixed methodology of both qualitative and quantitative research was employed. Figure 1 provides an outline of the project's steps.

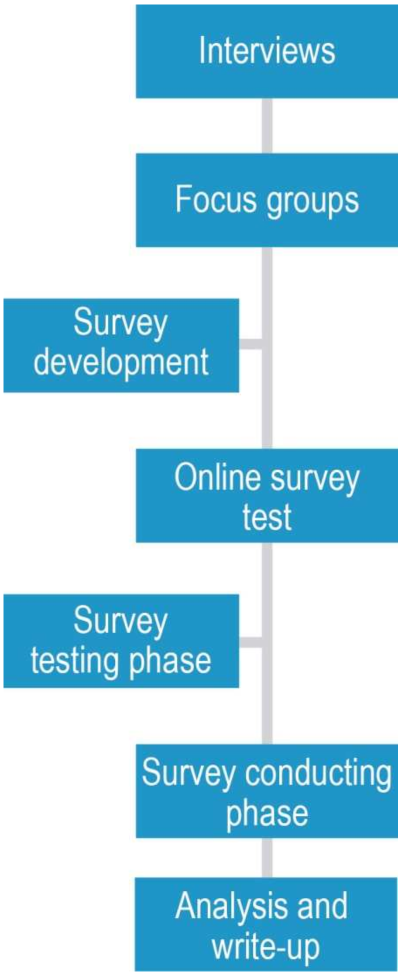

Figure 1: Process of research project

4 Qualitative investigation

Historically, lack of knowledge about CCS has led to methodological issues for CCS researchers, in that it is often difficult to assess attitudes towards a technology of which research participants have little knowledge. As a result, some researchers are adopting methods that provide respondents with information about CCS at the time data is gathered (see e.g. Duan, 2010; Palmgren, et al., 2005).

This project's qualitative research component aimed to explore public perceptions of CO_2 and identify common themes and attributes that would then inform the follow-up survey. An exploratory process was used in the interviews and focus groups. In each of the three countries, 18 one-hour interviews were conducted with participants from varied backgrounds (e.g., gender, age, education level, etc.) to understand how individuals understood CO_2. Interviews began with a series of open-ended questions regarding current knowledge and perceptions of CO_2 and CCS (as listed in Appendix A). Then, information was provided on CCS, and respondents were asked for their thoughts on the different stages of the process. To manage potential bias in the information, scientists who are experts in the CCS field developed it through an internal review process incorporating social scientists and engineers. Next, the interviews investigated how perceptions and understanding of CO_2 and CCS were influenced by the provision of different types of information. After information sheets were provided on where CO_2 is naturally found; commercial commodities that are in some way related to CO_2; and its properties, characteristics, and behaviour including during CCS, interviewees were asked whether the information had changed their perceptions and understanding of CO_2 and CCS. Interview results were analysed for common themes, and the information was collated to inform the material for focus groups.

Two focus groups were conducted in each country. The focus groups lasted approximately 2.5 hours and comprised six to eight participants from varied backgrounds (e.g. gender, age, education level, etc.). During the focus groups, participants were presented with information sheets on CCS and CO_2's characteristics and properties that had been informed by the earlier interviews. Afterwards, they completed brief questionnaires, discussed their perceptions of CCS, and explained whether they felt that the information was important for them when forming an opinion about CCS. Additional information was then presented on the consequences of CO_2 phenomena; how CO_2 behaves in CCS; and what would happen if CO_2 were to leak from pipelines or underground storage. Participants then discussed what effect this new information had on their perceptions of CO_2 and CCS. Further details of the focus group design can be found in Appendix B.

Significant qualitative findings from all three countries were listed and classified to make a draft of the survey questionnaire. The focus group material was analysed for recurring themes and apparent country differences.

5 Internet survey

Findings from the initial qualitative work gave important insights which were explored in more detail through a 25-minute internet survey, completed by 2,470 respondents. For additional details on recruitment, see section 5.2 below. All participants answered the same questions, but in the course of the survey they were presented with different types of information as described in the following sections. Figure 2 provides an overview of the survey sequence from beginning to end when it is read from top to bottom. “Outputs” at the right represent information collected by the survey.

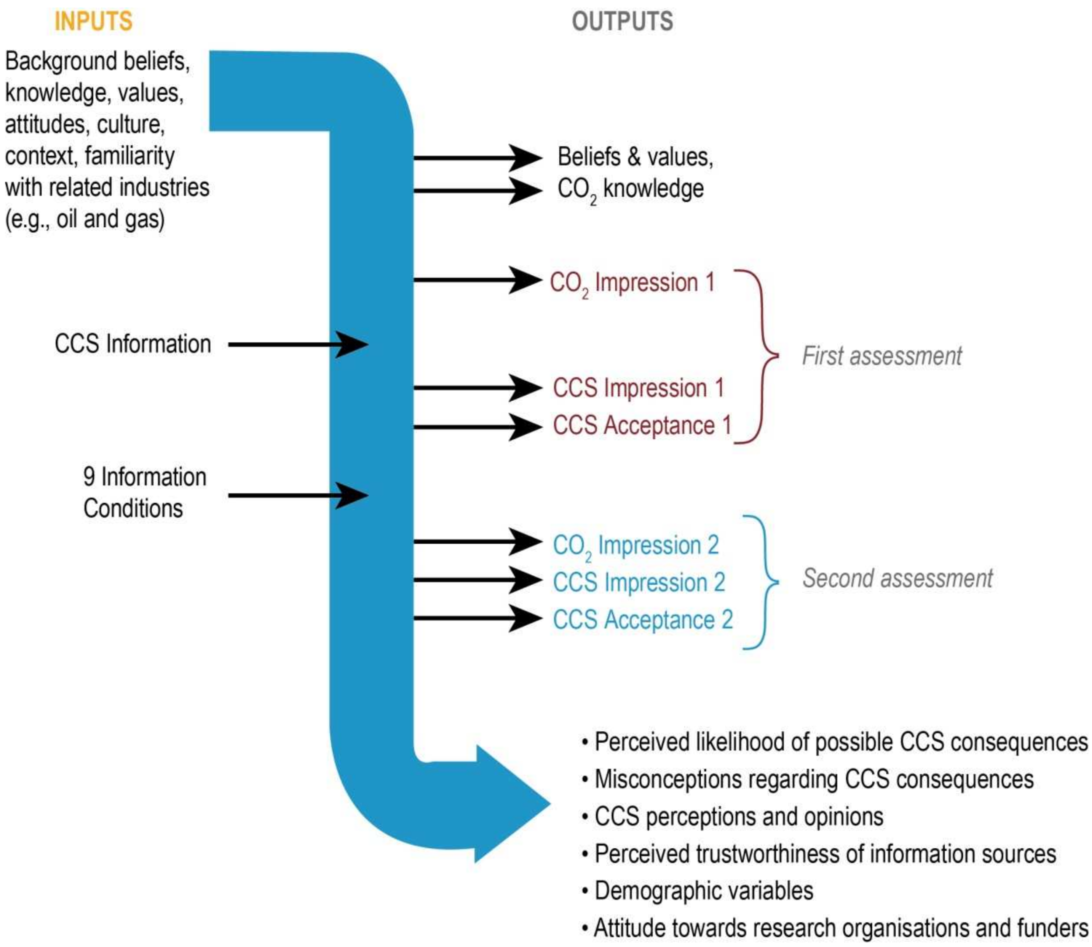

Figure 2: Overview of survey process

To test the effects of information provision, several measures were repeated before and after information was provided. The survey was designed in such a way as to incorporate nine conditions or versions that differed according to the combination of information about CO_2 presented to respondents. This design allowed the influence of different types of information to be tested, as described in section 5.4 below. A complete list of survey questions and pieces of provided information can be found in Appendix C.

The following sections describe the survey sequence.

5.1 Responses collected: Values and knowledge of CO_2

The first part of the survey was identical for all participants. It requested participants' values and beliefs about climate change and renewable energy, and it recorded their knowledge of CO_2's characteristics, effects, sources, and uses. These questions were based on the concepts that were often raised by respondents in the interviews and focus groups. Additionally, respondents rated how sure they were of their answers on a 1 to 5 scale, where answer option 1 indicated they were sure the given statement was not true; answer option 5 indicated they were sure that the given statement was true; and answer option 3 indicated that they were uncertain of their response.

5.2 Information provided: CCS introduction

Next, the survey presented respondents with brief introductory information on CCS, including an explanatory diagram of the technology. The information was based on an introductory text developed for and used in previous research into CCS perceptions of the lay public by the European-funded *NearCO2* project (Upham & Roberts, 2011).

5.3 First assessment: CO2 impression, CCS impression and CCS acceptance measures

Impressions of CO_2 and CCS were measured before and after respondents received additional information about CO_2 and CCS. They were measured using four scales with opposing adjectives on each end: 'negative-positive;' 'dirty-clean;' 'useless-useful;' 'dangerous-safe;' and for CCS, an additional scale: 'developing technology-mature technology.' Respondents could indicate which adjective on the scale best represented their impressions of CO_2 and CCS. In addition, respondents indicated to what extent they would oppose or accept implementation of CCS storage in their country, neighbourhood, and offshore under the seabed of their nearest sea. In the analysis, this first set of questions on CO_2 and CCS is referred to as the *first assessment*.

5.4 Information provided: The nine conditions

After the introductory text on CCS and the first measures of CO_2 and CCS perceptions and acceptance, the overall sample of respondents was divided into nine separate conditions, each of which received information from one or more of four different sets:

- *CO_2 properties* (Information part A) listed information on CO_2's chemistry, properties, toxicity, and uses; the greenhouse effect; and places where CO_2 exists.
- *CO_2 impact and natural phenomena* (Information part B) described CO_2's impacts and natural phenomena involving it, e.g., hot springs with CO_2 in Japan and Germany and the Lake Nyos incident.
- *CO_2 behaviour in CCS* (Information part C) described how CO_2 would behave at the injection stage, storage stage, and in the occurrence of CO_2 leakage during CCS. This text was largely based on the information provided in the Information Choice Questionnaire (de Best-Waldhober, et al., 2009) and checked by experts for accuracy and balance.
- *Control* (Information part D) repeated the introductory information and diagram of CCS presented earlier in the survey.

Respondents were provided with either only one of these four information packages, or combinations of them, creating conditions as shown in Table 1 below. Measures used in the analysis determined whether the provision of information influenced respondents' understanding and perceptions of CO_2 and CCS.

Table 1: Combination of information presented within survey conditions

Condition	Combination of information
1	Part A – CO_2 properties
2	Part B – CO_2 impact & natural phenomena
3	Part C – CO_2 behaviour in CCS
4	Parts A and B – CO_2 properties and CO_2 impact & natural phenomena
5	Parts A and C – CO_2 properties and CO_2 behaviour in CCS
6	Parts B and C – CO_2 impact & natural phenomena and CO_2 behaviour in CCS
7	Parts A, B and C – CO_2 properties, CO_2 impact &natural phenomena, and CO_2 behaviour in CCS
8 (Control 1)	Part D – Information and diagram on CCS
9 (Control 2[a])	Part D – Information and diagram on CCS (*Question order*: *10, 13, 14, 15, 11, 12*)

[a.] Control condition 2 was identical to Control condition 1; however, for Control 2, the questions measuring CCS perceptions and acceptance of implementation were presented later in the questionnaire instead of directly after the provided information. This was done to explore the effect of questions in this second part of the survey on respondent's perception and acceptance after the completion of the questionnaire. Apart from the order of these questions, the survey was identical for all respondents.

5.5 Second assessment: CO2 impression, CCS impression and CCS acceptance measures

Following the provision of information, respondents were assessed for a second time on their perceptions of CO_2, perceptions of CCS, and opinions on whether they would accept CCS implementation. This was considered the *second assessment*.

5.6 Responses collected: Additional CCS perceptions and demographic information

Several questions were then asked to examine respondents' understanding of CO_2's behaviour and the consequences of CCS. First, respondents could indicate how likely they believed it to be that certain potential consequences of CCS would occur using a 5-point scale ranging from '1' (not likely), to '5' (very likely)[6]. Second, respondents were provided with statements about true and untrue consequences of CCS. For each, they were able to indicate whether they believed it was a possible consequence or not on a similar 5-point scale, where '1' meant they were certain it could not occur, and 5 meant they were certain it could occur[7]. Finally, respondents received another set of statements containing arguments about CCS brought forward by people in the interviews and focus groups. For each statement, the respondents could indicate to what extent they agreed on a 5-point scale.

[6] This was referred to as the "likelihood" section.

[7] This was referred to as the "misconception" section.

The final section of the survey collected data on respondents' trust in information sources and demographic characteristics. It included a set of questions that related back to the introductory information provided as part of ethical requirements. Before commencing the survey, respondents had been informed of the research organisations conducting the research and the source of funding for the research project (i.e., the Global CCS Institute). These questions were designed to gauge whether the respondent had taken this information into consideration and what effect it may have had on their perceptions of the survey; for example, on their belief whether the information that had been provided was trustworthy and impartial.

6 Administration of the survey

6.1 Testing phase

Eighty respondents from Australia, 78 respondents from the Netherlands, and 816 respondents from Japan participated in testing the survey to examine whether the questions were clear and coherent. At five different stages throughout the survey, half of the respondents were randomly presented with an additional question about its clarity. Respondents who found any parts difficult to understand or answer were asked to provide details in their own words. The testing phase also assessed the online survey's implementation and functionality to ensure consistency across all three countries. Any important feedback from this process was incorporated into the implementation phase.

6.2 Implementation phase

The internet survey was completed by 2,470 respondents in total, with over 800 respondents from Australia, the Netherlands and Japan (see Table 2). Respondents completed the survey online and were randomly presented with one of the nine survey conditions. As a result, each survey condition was provided to between 266 and 287 people.

Table 2: Administration of the survey

Country	Survey period	Testing phase *N*	Response Rate	Conducting phase *N*	Response rate
Australia	April , 2010	80	48.8%	809	72.5%
Japan	March-April , 2010	816	36.7%	813	36.6%[8]
Netherlands	April , 2010	78	Not available	848	47%

In the testing phase, the Japanese researchers had a phenomenal response to their request for participants to trial the survey, hence the significantly larger number. Japanese panels were directly sampled from the population, whereas the Australian and Dutch panels were sampled via the registered panels of polling firms as described in Appendix D. The different recruitment methods resulted in a variance in response rates. All panels of questionnaire participants closely resembled national average demographics, with one exception: Australian survey recipients were more likely to have completed bachelor's degrees and masters' degrees. Additional details on the breakdown of panel participants by gender and age is found in Appendix D.

[8] In testing phase in the Japanese survey, a polling firm was used for sampling in order to trial the survey. In the conducting phase, the sample was directly taken from Japanese population. Respondents recruited directly from the population were not necessarily accustomed with participating in a survey like respondents registered as a panellist used by polling firms, which the Dutch and Australian countries used. That might be a reason of the lower response rate for Japan in the conducting phase.

6.3 Statistical analysis

The survey data was analysed using both descriptive and inferential statistics. *Descriptive statistics* included the frequency of responses and mean (average) responses as appropriate. *Inferential statistics* included correlations, cross tab analyses with chi-square tests, analysis of variance, and multiple regression analysis as appropriate to identify substantive differences between the groups of respondents.

- Cross tab analyses with chi-square tests were used to detect categorical effects such as difference by country and by the respondent's level of knowledge.
- Paired t-tests were conducted to compare between the first assessment and the second assessment on CO_2 impressions, CCS impressions, and opinions on CCS implementation.
- ANOVA and multiple regressions were conducted between the first assessment and the second assessment to explain the effect of providing information on CO_2 impressions.
- Finally, additional sets of multiple regressions were conducted to explain the factors influencing the formation of overall impressions on CO_2 and CCS and opinions on CCS implementation.

For regression analysis, stepwise methods were used where the threshold probability for entry was 0.05 and that for removal was 0.01. The final output was called "the best regression." Independent variables were adopted from the responses to questions in the questionnaire, and ranged from demographic variables, to values and beliefs, to opinions. These variables and categories are shown in Appendix C.

Part III Results

7 Results

7.1 Qualitative results

The following sections describe interview and focus group results regarding respondents' knowledge and perceptions of CO_2 and CCS, as well as reporting on the effect of providing information. Sample quotations from interviews and focus groups are presented in Appendix E.

7.1.1 KNOWLEDGE AND PERCEPTIONS OF CO_2 AND CLIMATE CHANGE

All respondents from the interviews and focus groups (except one member of an Australian focus group) were aware of CO_2, but the majority found it difficult to describe specific characteristics or properties of the gas. Respondents had a fairly basic understanding of where CO_2 exists. Most respondents understood that it is absorbed by plants, but were unaware that it is also absorbed by oceans. Respondents largely knew that air contains CO_2, but they were uncertain of its concentration. They commonly held the mistaken belief that CO_2 was harmful to the ozone layer and that it caused air pollution in the same way that soot does. Burning of fossil fuels was commonly described as a source of CO_2, particularly in automobile engines and petroleum combustion. Knowledge of CO_2's uses was fairly limited, with some respondents mentioning that CO_2 is used in fire extinguishers and by plants during photosynthesis, while many were unable to comment.

Respondents tended to perceive CO_2 negatively, with many indicating that it is harmful to the environment. Carbon dioxide was described during the interviews as causing climate change, and many thought that CO_2 emissions should be reduced. Some respondents thought of CO_2 as 'dirty' and associated it with air pollution. Focus group respondents tended to agree that CO_2 was hazardous and a waste material. Some mistakenly believed that CO_2 is flammable and explosive; contributing to their impression that it is harmful to humans. A small number of responses were somewhat positive, with respondents recognising that CO_2 is naturally occurring and an essential part of ecosystems.

All respondents had heard of climate change, global warming, or both; and the majority indicated that CO_2 emissions were the cause. Respondents in all three countries commonly misunderstood the mechanisms of climate change, seeing it as the result of ozone layer depletion from CO_2 emissions. A small number of respondents, particularly in the Netherlands, were sceptical towards climate change or questioned whether CO_2 emissions were the cause.

Interviews also addressed climate change mitigation measures. Respondents generally described actions such as reducing CO_2 emissions and using less energy. However, very few respondents mentioned direct measures for large scale or industrial emission sources such as power plants.

7.1.2 KNOWLEDGE AND PERCEPTIONS OF CCS

Awareness of CCS varied across the three countries. Very few interviewees from Japan or Australia had heard of it. Those interviewed in the Netherlands had greater awareness, with some referring to the Barendrecht project[9]. The term "carbon capture and storage" was similarly unfamiliar to members of the focus groups in Japan and Netherlands, but somewhat more familiar to Australian focus group members. Those who had never heard of CCS had varying mental images of the process; they imagined that CO_2 is stored in containers, or compared CCS to nuclear waste storage.

Perceptions of CCS, measured after basic information on the technology (but not on CO_2 at this point in the survey) were presented, varied by country. Many respondents in Japan had a favourable attitude towards CCS, whereas the vast majority in Australia were negative towards it, and perceptions in the Netherlands were mixed. Respondents believed that CO_2 leakage was inevitable and a high risk and that CCS is only a short term solution to reducing CO_2 emissions. Some also believed that CCS is limited by available storage capacity. Respondents with more favourable perceptions recognised CCS as a feasible mitigation strategy and a developed technology.

Respondents across all three countries tended not to support the planning of a CCS project near their homes. However, impressions of onshore and offshore storage varied. Respondents in Australia tended to see offshore storage negatively owing to potential or perceived impacts on the ocean. By contrast, Japanese survey respondents had more favourable impressions of offshore storage owing to its perceived minor effect on humans. Across the interviews and focus groups, respondents in the Netherlands slightly favoured offshore rather than onshore storage.

7.1.3 EFFECTS OF PROVIDING INFORMATION

Information on where CO_2 naturally occurs and how it is used in commercial commodities promoted greater understanding of CO_2 among respondents, but did not drastically change their opinion or perception of CO_2 and CCS. Respondents were surprised to learn how widely CO_2 existed around them, both naturally and in commercial uses. They were particularly interested in the natural phenomena of Lake Nyos, Mt Mammoth, and the Jackson, McElmo, and St. John's Domes[10]. The former two examples caused concerns and reinforced perceived risks and dangers of CCS. There were mixed reactions to the example of the Jackson, McElmo and St John's Domes. Some saw these as demonstrating that CO_2 could remain trapped for a long period of time, whereas others commented that CCS, because it is carried out by people, is different to the natural underground occurrence of CO_2.

Information regarding CO_2's properties was particularly influential in changing people's perceptions of CO_2 and CCS. Perceptions became more positive as previous misperceptions regarding explosiveness, flammability, and toxicity were dispelled. However, some respondents were confused by the fact that CO_2 was described as non-toxic, yet hazardous at certain concentrations. Also, respondents were interested to learn about the behaviour of CO_2 at different stages of CCS, and considered this information to be important. Descriptions of what could occur after CO_2 is

[9] Barendrecht was the first proposed onshore CCS project in the Netherlands, which was cancelled in February 2011 due to lack of public support.

[10] In the USA, CO_2 fields called the Jackson, McElmo, and St. John's Domes were formed millions of years ago, and together hold 2.4 billion tons of CO_2. This exemplifies how CO_2 has been securely sealed underground in natural underground CO_2 reservoirs for millions of years.

injected underground were particularly concerning to respondents. This information was seen to demonstrate the risks involved, such as potential impacts to groundwater and soil chemistry.

Overall, feedback collected in the interviews and focus groups confirmed that respondents lacked a full understanding of CO_2. Significant knowledge gaps on topics ranging from properties to commercial uses reinforced the requirement to include basic and wide-ranging information within the questionnaire, and for that information to address common misperceptions (e.g., the mechanism of climate change). The provision of information produced a variety of reactions from respondents and highlighted the importance of capturing their diverse views within the quantitative study. Since respondents considered the provision of certain types of information to be particularly important, these topics (i.e., where CO_2 is naturally found, how it behaves after injection during capture and storage, and the consequences of potential leakage) were emphasised in the internet survey.

7.2 Quantitative results

The following sections describe the results of the quantitative survey study conducted with 2,470 respondents across Australia, Japan and the Netherlands. These sections compare values and beliefs on the environment and energy issues across countries, and examine perceptions of CO_2, perceptions of CCS, and opinions on the implementation of CCS (alternatively referred to as "CCS acceptance"). In considering these results, it is important to remember that the Australian survey panel was slightly more educated than the general public, although an additional statistical test has shown that this did not affect the results. Additional selected tables and interpretative text are presented in Appendix F.

7.2.1 VALUES AND BELIEFS

Respondents' values and beliefs on environment and energy issues were assessed at the beginning of the survey. Respondents were asked to indicate the extent to which they agreed with a series of opinions on the importance of addressing climate change; promoting renewable energy; addressing fossil fuel depletion; accepting risks associated with new technologies; and increasing taxes to address climate change. Overall, respondents were moderately concerned about climate change and energy issues (see Figure 3); however, there were significant differences among countries, and these differences are expanded on in the bullet points below.

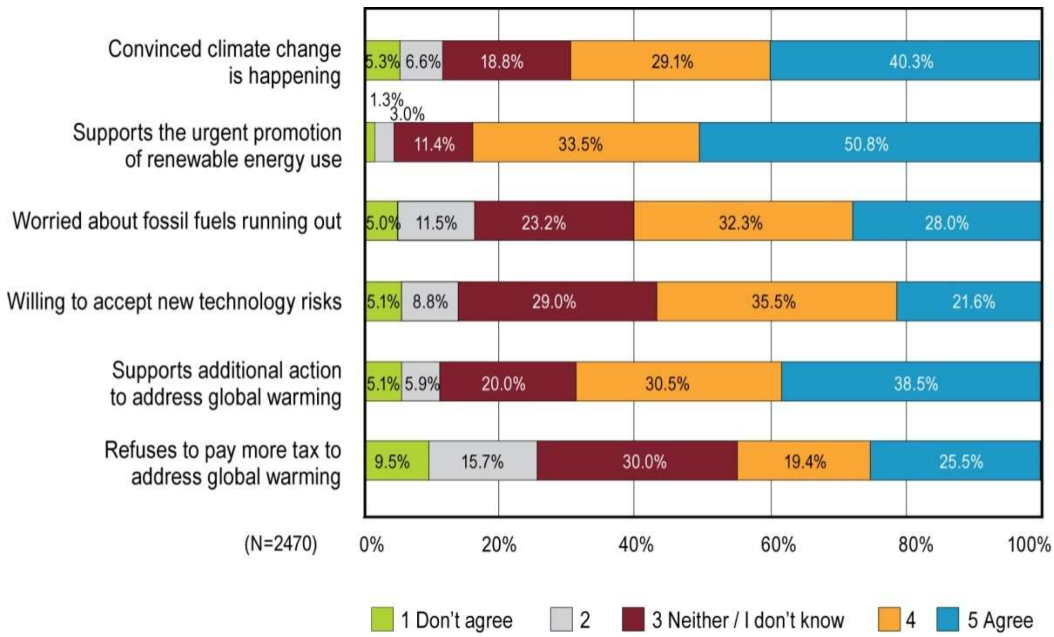

Figure 3: Opinions from all participants about energy and environmental issues

- Respondents were first asked whether they agreed with the statement "I am convinced climate change is happening." The majority of respondents in each country were at least somewhat convinced, but strength of agreement varied significantly across countries. Belief in climate change was significantly greater in Japan, with 70% of respondents convinced that climate change is happening (m = 4.49, SD = 0.95). Respondents in the Netherlands were much less convinced (m = 3.58, SD = 0.98). Only 15.9% answered *I agree* and almost a third (29.2%) neither agreed nor disagreed. In Australia, over one third of respondents (35.4%) were convinced climate change is happening; yet Australia also had the highest frequency of respondents who were unconvinced (9.4%).

- Respondents' belief in climate change correlated strongly with views that action should be taken on it, with r = .73 ($p < .001$). Overall, most respondents believed immediate action should be taken to address climate change. Respondents in Japan agreed most strongly with taking immediate action (62.6%), compared to 33.9% in Australia and 19.7% in the Netherlands. Levels of uncertainty were highest in the Netherlands (30.5%). The frequency of those who did not agree that something should be done about climate change was highest in Australia (9.5%).

- When asked whether they agreed that "We should promote the use of renewable energy as soon as possible", the majority of respondents supported this statement. However, the number of respondents agreeing most strongly was significantly higher in Japan (70.4%) than in Australia (47%) and the Netherlands (35.7%). Out of all the opinions presented to respondents, they most frequently agreed on the need for promoting renewable energy. In total, only 11.4% of respondents answered that they did not know whether renewable energy should be promoted as soon as possible.

- Respondents were moderately concerned that fossil fuels will run out (m = 3.67, SD = 1.15). The frequency of those who agreed most strongly with the statement "I am worried about fossil fuels running out" was highest in Japan (47.5%), representing over twice that of Australia (20.6%) and the Netherlands (16.3%).

- Willingness to accept some risks in relation to new technologies was generally similar across Japan (m = 3.62, SD = 1.19), Australia (m = 3.66, SD = 1.07) and the Netherlands (m = 3.52, 0.96). In Japan, almost one third of respondents (30.8%) thought it is important to accept some risks with new technologies, while over a third (35.8%) were uncertain. The majority of respondents in Australia and the Netherlands were somewhat in agreement that it is important to accept some risks.

- Willingness to pay additional taxes to address climate change was similar across Australia (m = 3.45, SD = 1.33), Japan (m = 3.26, SD = 1.34), and the Netherlands (m = 3.35, SD1.14). Compared to the previous questions, a greater variety of opinions existed regarding a tax increase. Results show that although Japanese respondents had a greater tendency to view climate change as an immediate issue, they were not more willing to pay more to address it. Of all the countries, respondents in Australia most frequently stated that they would refuse to pay more tax to address climate change (31%). A negative and significant, but low ($r = -.20$, $p < .001$) correlation existed between the conviction that something should be done about climate change and the refusal to pay additional taxes, meaning that those who believed that something should be done had a slight tendency towards willingness pay more taxes.

7.2.2 KNOWLEDGE OF CO_2

After the assessment of values and beliefs, questions in the survey measured respondents' knowledge of CO_2's properties, sources, uses, and effects before they were presented with any information on CO_2. Respondents rated how sure they were of their answers on a 1 to 5 scale, where answer option 1 indicated they were sure the given statement was not true; answer option 5 indicated they were sure that the given statement was true; and answer option 3 indicated that they were uncertain of their response.

Properties

Knowledge about CO_2's properties varied greatly by topic as well as by country. Most respondents were aware that CO_2 occurs naturally and is contained in air. Even in these cases, however, over one fifth of the respondents were not sure. Significantly more respondents in the Netherlands were unsure whether air contains CO_2; 76.6% believed (correctly) that this was the case and 36% were uncertain. On the other hand, in Japan, 83.5% thought air contains CO_2, with 68.9% being very sure. Essentially, even though the Dutch respondents tended to pick the right answer, they were much less certain of their responses.

According to research of Hofstede (1980) there are some cultural differences between the Netherlands and Japan on the notion of "uncertainty avoidance". Hofstede argues that the anxiety that is created by uncertainty is resolved by developing religion, laws and technology. Japan is considered a country with high uncertainty avoidance, while the Netherlands is considered moderate in uncertainty avoidance. We can therefore not rule out that cultural differences may have influenced this difference in results between the Netherlands and Japan; Japanese participants may be more inclined to avoid uncertainty and indicate that they are more certain of their answers. However, since Australia is usually considered as a "western" country with similar values and traits as in Europe, they would be more likely to resemble the Netherlands concerning uncertainty avoidance. Since Australian responses tended to resemble the Japanese more than the Dutch, it thus seems unlikely that such cultural factors have a large impact on the present results.

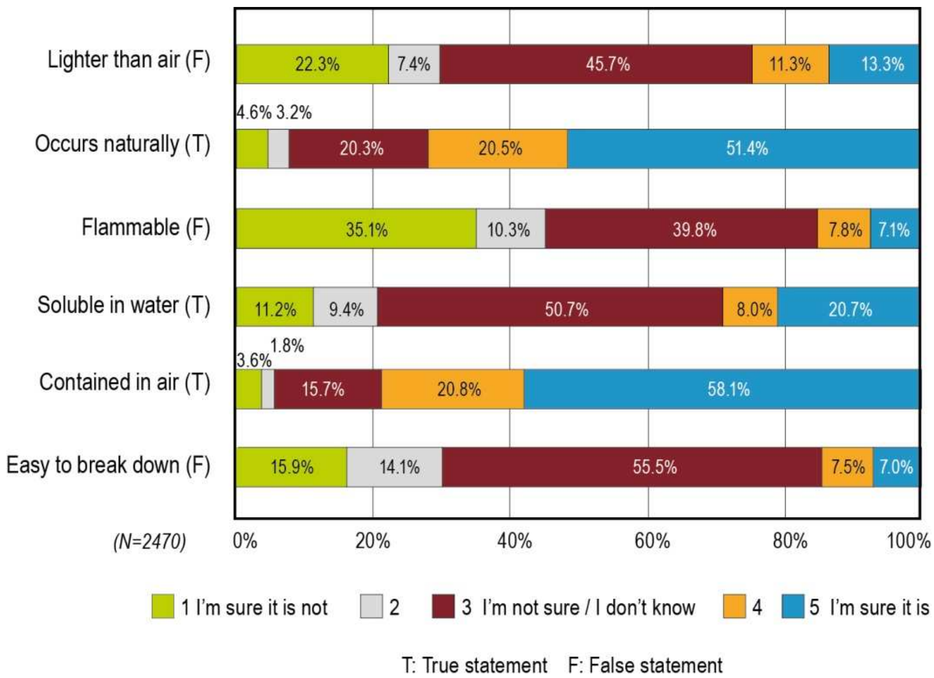

Figure 4: Knowledge of all participants of CO2's properties

Respondents were highly uncertain about CO_2's other properties. In the case of flammability, over one third of respondents stated that CO_2 is not flammable, but over half either believed it was flammable or were unsure. Japan had the highest percentage of respondents (48.0%) who were sure it was not flammable, compared to 40.2% in Australia and only 23.3% in the Netherlands. Around half of respondents were not sure whether CO_2 breaks down easily, is soluble in water, or is lighter than air. In Japan, significantly more people knew CO_2 is soluble in water: 44.3% in total versus 22.7% in Australia and only 18.7% in the Netherlands.

Sources

The majority of the respondents seemed familiar with CO_2's sources. Over half of the respondents knew that CO_2 is released during electricity production from natural gas or coal, yet over one quarter (26.6%) were unsure. Almost half of the respondents were unsure whether the CO_2 emitted from industrial sources is chemically different from naturally occurring CO_2, but over a quarter believed it was indeed the same.

A majority of the respondents knew that the human body produces CO_2, but here again over a quarter (26.3%) were unsure whether it does and 5.2% thought it does not. Cultural differences were significant: in Japan, 73.7% of respondents were very sure that the human body produces CO_2, compared to 51.9% in Australia and 28.4% in the Netherlands. In the Netherlands, as with the "properties" questions, a considerable amount of respondents thought that the body does produce CO_2, but were not sure: 27.9%.

A large majority of respondents stated CO_2 is absorbed by plants, and over one half (60.6%) were sure of this. In the Netherlands, again, also over one half of respondents stated that CO_2 is absorbed by plants, but fewer respondents (37.5%) were certain compared to Japan and Australia (over 60% in both cases). In all three countries, respondents were unsure whether CO_2 is absorbed by oceans; close to half did not know whether this was true or not.

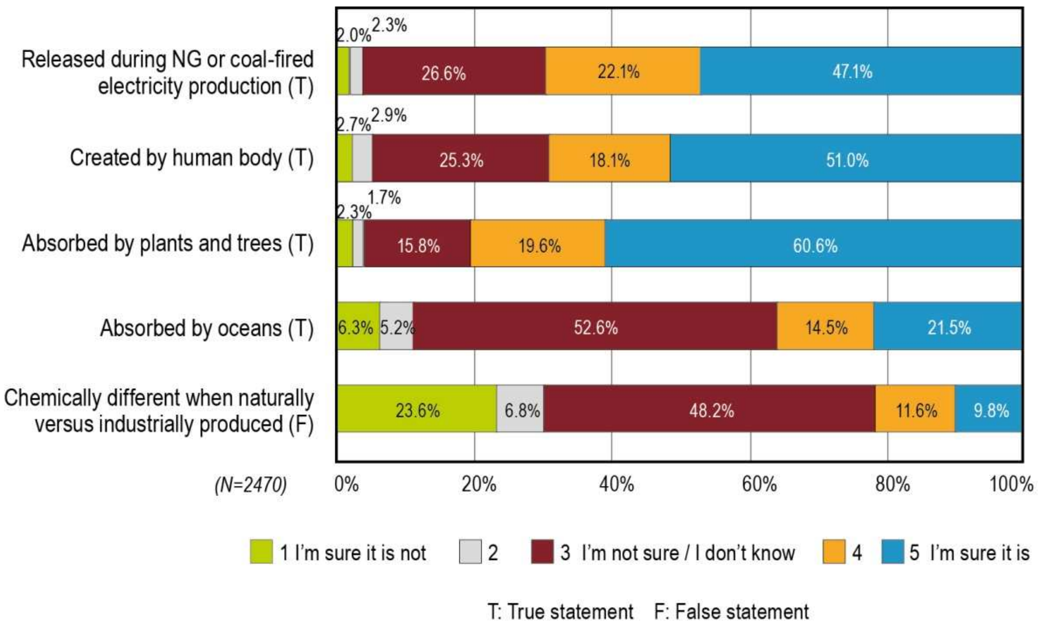

Figure 5: Knowledge of all participants of CO_2's sources

Uses

Respondents were asked about their knowledge of CO_2's industrial uses. The best known use of CO_2 was in fire extinguishers (17.9% were aware of this possible use). One third believed or were sure CO_2 is used to make drinks fizzy (e.g., cola and soda). People were less familiar with the use of CO_2 for the purpose of enhancing plant growth in greenhouses, about which over half of the respondents were unsure. The incorrect statement that CO_2 is used to make tyres had the highest percentage of "unsure" answers: over 75%.

Overall, Australians (for whom the survey panel slightly over-represented highly educated individuals) were significantly more aware of the uses of CO_2 than the other countries. In Australia, 48.2% of the respondents were aware that CO_2 is used to make soft drinks and beer fizzy, compared to 37.6% in Japan and 17.1% in the Netherlands (Chi-sq = 173.79; df = 8; $p < .01$). Similarly, 59.7% of Australian respondents were aware of the use of CO_2 in fire extinguishers, compared to 40.4% in Japan and 43% in the Netherlands (Chi-sq = 143.65; df = 8; $p < .01$).

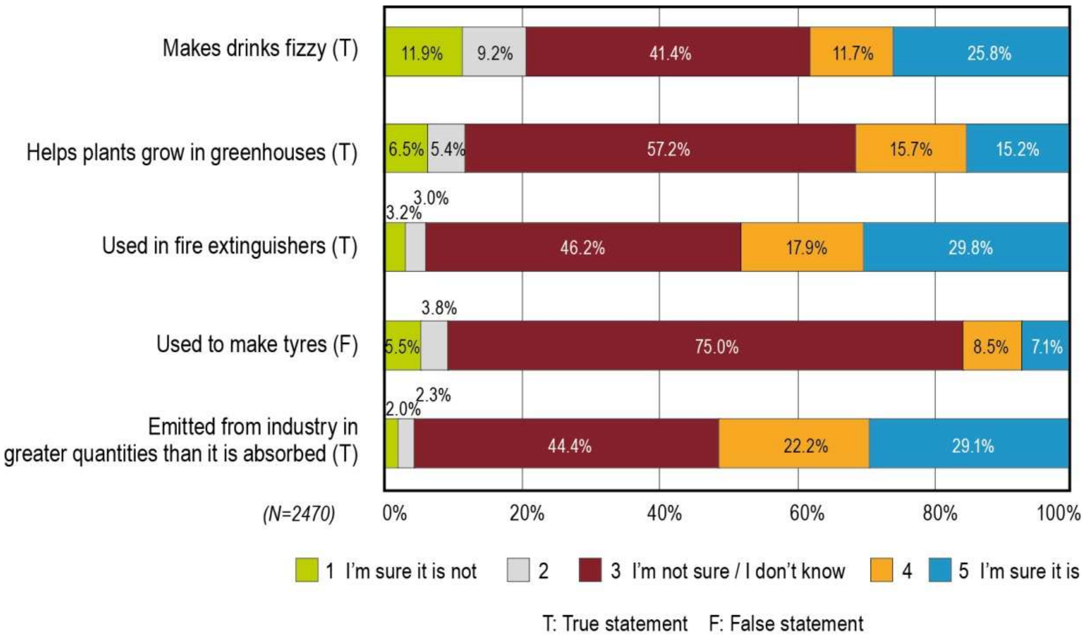

Figure 6: Knowledge of all participants of CO_2's uses

Effects

In the interviews, respondents ascribed several effects of other substances to CO_2, and the questionnaire results showed that these misperceptions also exist in the broader population.

- First of all, over half of respondents believed that CO_2 harms the ozone layer (56%); 15.9% stated it does not; while 28.1% were unsure about this. Japan had the highest percentage of people who were sure CO_2 affects the ozone layer, 52.4%, compared to 29.5% in Australia and 21.3% in the Netherlands.

- One third of respondents (32.4%) were either slightly or very sure that CO_2 affects human health in the same way as air pollution substances such as soot do, while 41.5% were unsure.

- The interviews showed apparent confusion between CO_2 and carbon monoxide (CO). The results of the survey confirmed that considerable uncertainty exists: 40.3% of respondents were unsure about whether CO_2 has the same effect on humans as CO.

- A majority of respondents thought or were sure that CO_2 influences the climate, and that plants and trees need CO_2 to grow. In the Netherlands, a much larger number of respondents thought that CO_2 influences the climate, but were unsure about this.

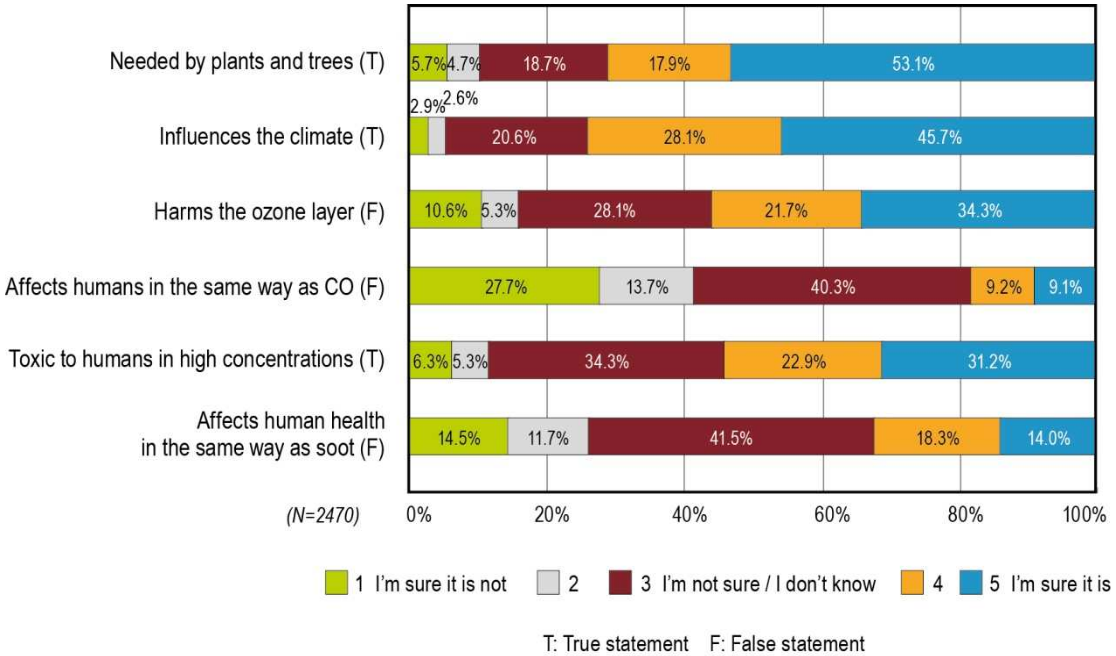

Figure 7: Knowledge of all participants of CO_2's effects

Overall knowledge levels across countries

In order to compare the knowledge levels between the countries, an overall knowledge score was computed. Respondents who answered an item incorrectly or were unsure about the answer received 1 point for this item. Respondents who chose the correct answer, but were not sure of the answer, received 2 points, and those who were sure of the correct answer received 3 points. The Japanese sample had the highest overall CO_2 knowledge score with a mean of 1.93, followed by the Australian sample (m = 1.80) and finally the Netherlands (m = 1.64). There was a statistically significant difference among the three countries ($F_{(2,2470)} = 95.16$, $p < .001$).

7.2.3 PERCEPTIONS OF CO_2

First assessment

Perceptions of CO_2 were assessed by asking respondents to indicate whether they perceived it as more "negative" or "positive", more "clean" or "dirty", more "useful" or "useless", and more "dangerous" or "safe". On all four scales, around half of respondents indicated that they did not have a specific opinion about these topics, choosing the option "Neither/Both equally." On average, people perceived CO_2 to be slightly negative (m = 2.69), slightly dirty (m = 2.68), and very slightly dangerous (m = 2.90). However, they did also perceive CO_2 to be slightly useful (m = 3.19).

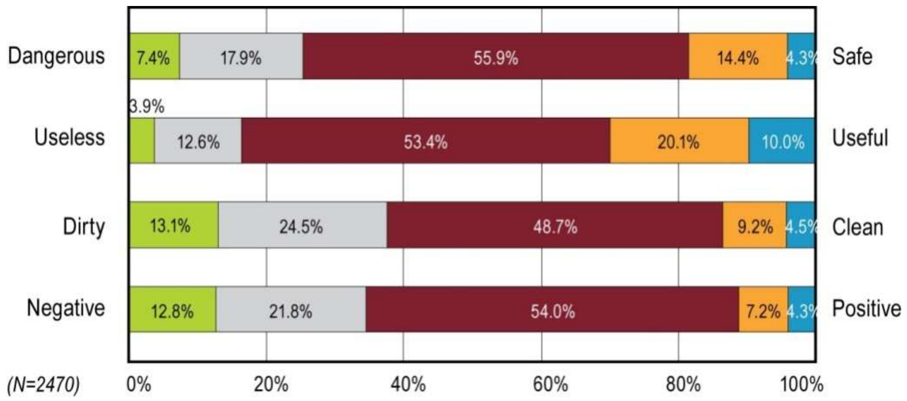

Figure 8: Impression of CO_2 by all participants (First assessment)

A regression analysis containing all of the knowledge items revealed which parts of the respondents' knowledge significantly influenced their perception of CO_2 and whether this influence was negative or positive. For results of the analysis, see Table 9 in Appendix F. Results showed that belief in global warming had the strongest influence on the perception of CO_2 as negative or positive. That is, a belief in global warming led people to perceive CO_2 more negatively (beta -0.14, $p < 0.01$). Belief that CO_2 is emitted from coal and natural gas fired power plants also had a strong effect (beta -0.15, $p < 0.01$). Respondents perceived CO_2 to be more dirty when they believed CO_2 is emitted from coal and natural gas powered power plants (beta -0.14, $p < 0.01$) and when they believed it has similar effects on human health as do air pollutants such as soot (beta -0.19, $p < 0.01$). The perception that CO_2 is dangerous was mainly caused by the belief that CO_2 has similar effects on human health as air pollutants such as soot (beta -0.12, $p < 0.01$).

The strongest influence on CO_2 being perceived as safe was exerted by the knowledge that CO_2 is needed by plants and trees to grow (beta 0.08, $p < 0.01$), but this influence was still quite weak. Considering CO_2 to be useful was mainly influenced by the extent to which they believed that plants need CO_2 to grow (beta 0.15, $p < 0.01$) and that CO_2 occurs naturally (beta 0.13, $p < 0.01$). The belief that CO_2 is used to make soft drinks fizzy made respondents consider CO_2 to be cleaner (beta 0.10, $p < 0.01$).

Second assessment

Respondents' perceptions of CO_2 were assessed for a second time following the provision of information. Results indicate a pattern very similar to the first assesment. The most notable shift was that more participants formed an opinion about CO_2 on all scales; in other words, fewer respondents chose the middle category. Yet extreme shifts in opinion hardly occurred, and over half of respondents did not change their opinion after receiving information.

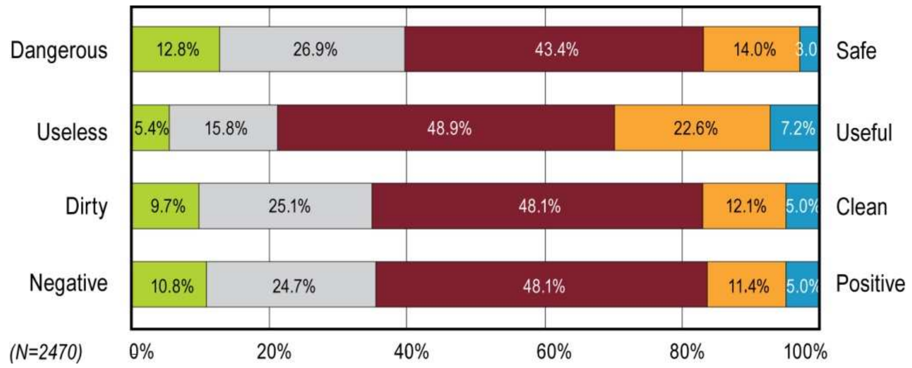

Figure 9: Impression of CO_2 by all participants (Second assessment)

Influence of information on CO_2 perceptions

To test the influence of the different sets of provided information (i.e., the nine "information conditions") on perceptions of CO_2, paired t-tests were used to compare the perception measures after the provision of information to the previous measures. For the results, see Table 10 in Appendix F. Overall, participants gave a similar pattern of responses on how they perceived CO_2 after receiving information packages, but more participants had formed an opinion in either the favourable or unfavourable direction. The results show that overall respondents became more positive about CO_2 and perceived it as more useful and clean after receiving only the information about CO_2's characteristics. This effect was not apparent when the information was provided in combination with one of the other information parts. Information about natural phenomena involving CO_2 made respondents perceive CO_2 as more dangerous compared to the respondents in the control condition.

In addition, ANOVAs were conducted to look for the effects of isolated components of the information package as well as the interaction effects between them, between the first and second assessments (see Table 11 in Appendix F). Results showed a significant but weak positive effect of the information package "CO_2 characteristics" (all $p < 0.01$), and a clear negative effect of the information package "CO_2 natural phenomena" (all $p < 0.01$), on the change of opinions of the three types of CCS implementation. Also, the information package "CO_2 behaviour in CCS" negatively influenced participants' opinions on implementing CCS in their countries and in their neighbourhoods (both $p<0.05$). No interaction effects were detected in the analyses, implying that the effects of information packages appeared in a cumulative way. Most of the remainder of this chapter will discuss the significant (but weak) effects of the subcomponents of these information packages.

7.2.4 AWARENESS AND PERCEPTIONS OF CCS

After the measures of CO_2 impressions and the introductory text about CCS, respondents were asked whether they had heard about CCS before receiving this information. About a half (53%) of all respondents had not, and one quarter of the remaining respondents (47%) answered that they had heard of it but did not really know what it is. Twenty per cent responded “I have heard about it and I know a little about it”, and only 5% responded “I have heard about it and I know a lot about it.”

The Netherlands showed the greatest awareness of CCS among the three countries, as 64% of respondents had heard about CCS to some extent. The quantitative results corresponded with the interview data, which showed that interviewees in the Netherlands had greater awareness of CCS than those in Australia or Japan. Japan had the lowest awareness of CCS, with only 35% of the Japanese survey respondents indicating that they had heard about it. In Australia, 40% of the survey respondents had heard about CCS; and 2.3% indicated that they knew a lot about it, which was comparable to the result in the Netherlands. Results also showed that awareness does not directly imply knowledge, as in all cases approximately one quarter of respondents indicated having heard about CCS, but not really knowing what it is.

A series of questions was asked on how likely participants believed various CCS consequences to be. Another series of questions addressed beliefs relating to CO_2’s effects in CCS. Analysis was conducted to determine how misunderstandings of CO_2’s behaviour in CCS are affected by misunderstandings of CO_2 and by information provision. Results are shown in Table 12 in Appendix F. Almost all misperceptions about CO_2 were found to be correlated to misperceptions about CCS. It was found that respondents’ level of misunderstanding of CO_2 was related to how risky they perceived CCS to be.

The following table summarizes results from regression analyses comparing participants’ misunderstandings of CO_2 to their knowledge of CCS, where a higher knowledge score means a better understanding of CCS. All variables describing misunderstandings of CO_2 were negatively correlated to the participant’s CCS knowledge score, and all variables describing correct understandings of CO_2 were positively correlated to CCS knowledge score.

Table 3: Effect of misunderstandings of CO_2 on understanding of CCS[a]

Category	Dependent Variables	Knowledge score, CCS std. coef	Question statement
Value and beliefs	MoreTax	-0.052**	I refuse to pay more tax to address climate change (global warming).
CO_2 property	Flammable	-0.109**	CO_2 is flammable.
	EasyBD	-0.035*	It is easy to break down CO_2.
CO_2 understanding	Climate	0.049*	CO_2 influences the climate.
	Ozone	-0.085**	CO_2 harms the ozone layer.
	CO	-0.100**	CO_2 has the same effect on humans as CO (carbon monoxide).
	Toxic	0.047*	CO_2 in high concentrations is toxic for the human body.
	Soot	-0.113**	CO_2 affects human health in the same way as air pollution substances such as soot.
CO_2 source	PowerPlant	0.118**	CO_2 is released during electricity production from power plants using natural gas or coal.
	PlantAbsorb	0.050**	CO_2 is absorbed by plants and trees.
	DifferentSubstance	-0.093**	Naturally occurring CO_2 has a different chemical structure to industrially occurring CO_2.
CO_2 uses	FireExtinguisher	0.052**	CO_2 is used in some fire extinguishers.
	Tyre	-0.048**	CO_2 is used to make tyres.
Provided InfoA	InfoProperty	0.079**	Properties: •Colourless •Odourless •Heavier than air, therefore accumulates in low-lying areas •Non-flammable •Non-explosive at normal pressure •Water-soluble
Provided InfoC	InfoCapture	0.194**	In industry the capture and compression of CO_2 is common practice. The risks associated with capturing CO_2 from the production process are well known and managed.
	InfoLeakCracks	-0.114*	If liquid-like CO_2 is stored appropriately, there is a very small chance that small quantities of it would leak through poorly sealed wells, tears and cracks in the caprock layer of the underground storage.
Provided InfoD	InfoWhatCCS	0.073**	*The same information CCS information provided to all respondents before 1st assessment of opinion on CCS implementation. See Appendix C*
Trustworthy source	LocalGov	0.064**	Local/regional government agencies/organisations
	NationalTV		National television programs that I watch
	NationalPaper	0.054*	National newspapers that I read
	LocalPaper		Local newspapers and television that I read/watch
	Scientist	0.073**	Scientists/researchers
	NationalNGO	-0.075**	National and/or international non-government organisations (NGOs) such as Greenpeace or WWF
	LocalNGO	-0.054*	Local NGOs and/or community groups, residents' associations etc.
	Friend	-0.059**	Friends, neighbours, family
	Website	-0.065**	Interactive websites (e.g. blogs, wikis etc.)
	UNagency	0.049*	United Nations organisations such as the Intergovernmental Panel on Climate Change (IPCC)
Information gathering topics	Physics	0.043*	Physics
	News	0.036*	News
	Science	0.061**	Science
Demographics	Female_dmy	-0.045*	
Adjusted R-squared		0.321	

[a.] Notes: *: significant level below 5% **: significant level below 1%

- (dark blue) Variable representing a correct understanding of CO_2 (extent of support to correct statement on CO_2)
- (magenta) Variable representing a misunderstanding of CO_2 (extent of support to wrong statement on CO_2)
- (light blue) Variable with positive & significant effects on knowledge score of CCS on (p<0.05 or p<0.01) in regression
- (pink) Variable with negative & significant effects on knowledge score of CCS on (p<0.05 or p<0.01) in regression

First assessment

Error! Reference source not found. below shows the first impressions of CCS, assessed after the basic CCS information was presented. Respondents indicated to what extent they perceived CCS to be positive or negative; clean or dirty; useful or useless; dangerous or safe; and a mature technology or a developing technology on a 5-point Likert scale. Most of the total respondent population had impressions of CCS as at least somewhat positive (48.5%), somewhat clean (48.2%) and somewhat useful (52.9%).

However, in terms of the safety and maturity impressions, most of the participants selected "3: Neither/Both equally", representing uncertainty. Yet those that did have stronger impressions, as demonstrated by answering 1, 2 or 4, 5, thought that CCS is "dangerous" (9.9%, 20.1%) rather than "safe" (15.9%, 6.9%). Similarly, with the maturity measures, more people thought CCS is a "developing" (18.5%, 20.2%) than a "mature" technology (13.7%, 4.7%).

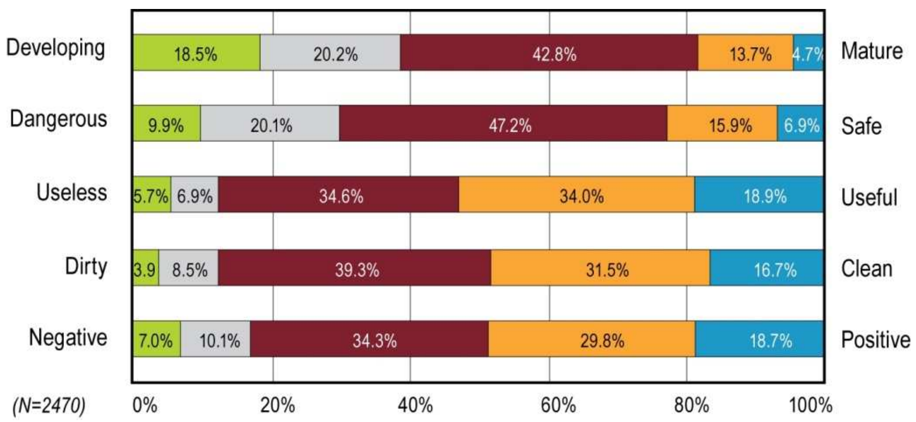

Figure 10: Impression of CCS by all participants (First assessment)

Factors influencing first CCS impression

To investigate factors related to the formation of first opinions of CCS, regression analyses were conducted with CCS impressions as dependent variables and CO_2 knowledge, CO_2 impressions, and respondents' demographics as independent variables.
Table 13 in Appendix F shows the results. An overview of the results discussed in the Appendix can be found in **Error! Reference source not found.** below.

Table 4: Factors influencing first impression of CCS

	Seeing CCS as …				
	A positive technology	Clean	Useful	Safe	Mature
Acceptance of risks related to new technologies	Positive influence beta 0.07	Positive influence beta 0.09	Positive influence beta 0.08	Positive influence beta 0.07	
Understanding that CO_2 influences climate			Positive influence beta 0.09		
Believing that CO_2 affects health as soot does					Positive influence beta 0.08
Knowing that CO_2 is emitted from power plants			Positive influence beta 0.8		Positive influence beta -0.07
Understanding that human body produces CO_2	Negative influence beta 0.6				Negative influence beta -0.11

Positive influence

Negative influence

Moving beyond these knowledge factors to consider how CO_2 impressions influenced CCS impressions, the only significant influence was exerted by the impression of CO_2 as "useful" (beta 0.04, $p < 0.05$). Looking at the singular impression items, perceiving CO_2 as useful made respondents perceive CCS as more useful as well, just as perceiving CO_2 as more dangerous makes respondents perceive CCS as more dangerous. This tendency was repeated in the case of "CO_2Clean"and "CCSClean", but the effect was relatively weak (beta 0.05, $p < 0.05$).

Self-rated knowledge and CCS impression

When respondents' self-rated knowledge was compared to their CCS impressions, higher awareness of CCS was generally linked to a lower percentage of "3: Neither/ Both equally" responses and a higher percentage of anchoring option responses (1 or 5). This implied that respondents with higher awareness and self-reported knowledge had more pronounced opinions. This was notably true for the "Safe" measure.

Respondents who rated themselves as knowing a little about CCS (i.e., those who selected "3: I have heard about it and I know a little about it" options in the awareness of CCS questions, 20.1% of the total), also tended to be favorable towards CCS. This 'little knowledge' group account for the highest percentages in "Positive" and "Useful" impression responses, and the second highest percentages of "4" and "5" answer options chosen in the other impressions. Among respondents who had "only heard about CCS" (i.e. who selected "2: I have heard about it but I don't really know what it is" options in the awareness of CCS questions – 24.5% of the total), only a few of them indicated their impression of CCS to be "Negative", "Dirty", "Useless", and "Developing technology". Almost a third, however, indicated to perceive CCS as at least somewhat dangerous. Among respondents who had never heard about CCS (i.e. who selected "1: No, I have not heard about it" options in the awareness of CCS questions, 53.2% of the total), many selected "3: Neither/ Both equally" in relation to the impression options.

Second assessment

Perceptions were assessed for a second time following the provision of an information package in accordance with the survey conditions. Across all information conditions, there was very little change in impressions of CCS as a result of information provision. About 60% of all respondents did not change their answers. The impression “Positive” had the highest rate of respondents who changed their answers in the negative direction, followed by “Clean” and “Safe”, which demonstrated a similar rate of change.

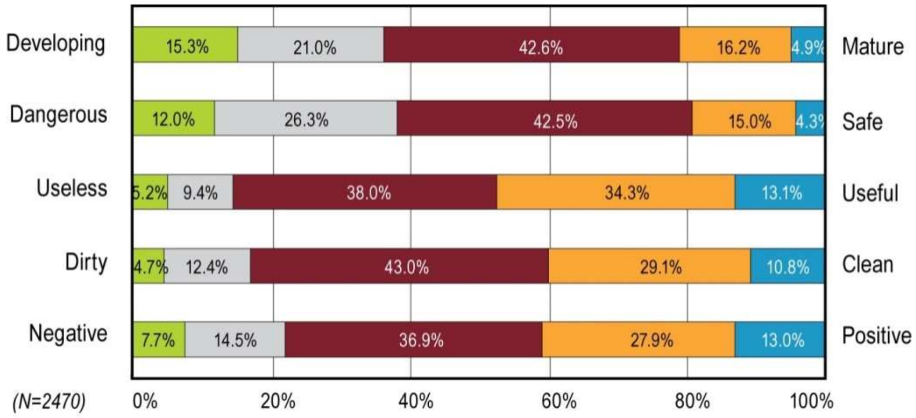

Figure 11: Impression of CCS by all participants (Second assessment)

Influence of information conditions on perceptions

Results of the second assessment were analysed using an ANOVA to see whether CCS impressions are influenced by any particular type of information. Results are in Table 14, Appendix F. In brief, providing information on natural phenomena damaged impressions of CCS ($p < 0.01$) and decreased its tendency to be seen as “safe” ($p < 0.01$) , yet combining this information with information on CO_2 characteristics mitigated the negative impact on this scale caused by the information “CO_2 natural phenomena.” Providing information on CO_2’s behaviour in CCS decreased the perception of CCS as “clean.” The impression that CCS is “Mature” was influenced positively by the information “CO_2 characteristics” and “CO_2 behaviour in CCS” (both $p<0.01$). No information package changed impressions of CCS as “useful.”

Also, a regression analysis was conducted to check the impacts of each information segment on the change in CCS impressions between the first and second assessments. Its results are in Table 15, Appendix F. The results of the regression analysis indicated the impacts of each information segment on the change of CCS impressions are as follows. Information about Mount Mammoth and about CCS possibly inducing micro earthquakes had a negative impact on impressions of CCS ($p < 0.01$ in both cases). Information on the chance of CO_2 leakage was found to relate to perceptions of CCS as “dirty.” Information on CO_2 toxicity (covariate “InfoToxicity”) affects the impression of CCS’s maturity as a technology (beta 0.06, $p<0.01$). Also, the information on CO_2 capture (covariate “InfoCapture”) impacted positively on the impression “Mature” (beta 0.09, $p<0.01$), seemingly because the information includes the already existing industrial practice of CO_2 capture process and ability of risk management.

Finally, regression analyses were conducted with the CCS impressions measured in the second assessment as dependent variables and CO_2 knowledge, CO_2 impressions, misperception/ understanding of CCS, and respondents’ demographics as independent variables.

Table 16 in Appendix F shows the results of the best regression. The model fits (the adjusted R-squares) were much increased compared to the regression on the first assessments. Therefore this regression showed the effects of CO_2 knowledge, CO_2 impressions, misperception/ understanding of CCS, and respondents' demographics comprehensively.

CCS impressions were influenced by respondents' understandings/opinions on CCS, especially the understanding that CCS posed too many risks for human health (covariate "Many Risk", negative impacts) and the opinion that CCS was essential to mitigate climate change (covariate "MitigateCC", positive impacts) which impacts were constantly significant and strong on all five CCS impression measurements. The regression analyses also showed the results of positive impacts of second assessment of CO_2 impressions on CCS perceptions. For example, respondents who perceived CO_2 positively tended to perceive CCS positively. As for maturity of CCS, Dutch dummy variable was significant and positive probably because respondents in the Netherlands were most aware of CCS and would have the most knowledge on it among three countries.

7.2.5 ATTITUDES TOWARDS CCS IMPLEMENTATION

First assessment

Apart from their impressions of CCS, respondents were also asked about their opinion on CCS implementation in their country, their neighbourhood and in the seabed under the nearest sea. We found around 40% of participants showed neutral opinions on CCS implementation. Neutral opinions account for 42% for "in your country", 40% for CCS "in your neighbourhood (onshore)" and 39% for CCS "in the seabed offshore". Meanwhile, for CCS "in your neighbourhood (onshore)" the majority of participants showed negative opinions, accounting for 43% of all responses. For "CCS in your country", more respondents showed positive opinions (36%) than negative opinions (22%). Finally, as for "CCS offshore", the percentage of respondents who showed positive opinions is about the same as the percentage of respondents who showed negative opinions.

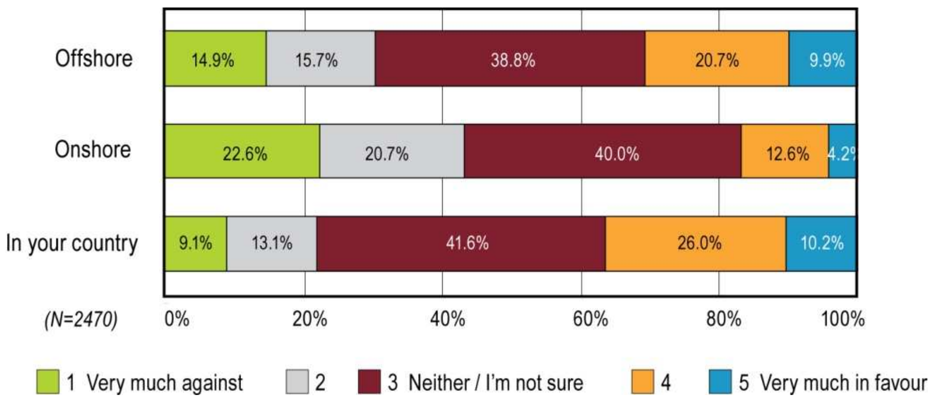

Figure 12: Opinions on CCS implementation from all participants (First assessment)

Note: For clarification, 'onshore' in the graph refers to 'in your neighbourhood' proximity

We analysed the factors which contributed to the forming of initial opinions. The first assessment was conducted after showing participants an introduction into CCS and the capture, transport and storage process contained in a simple cartoon. Since most of participants had never heard about CCS or did not know about CCS, only a small portion of respondents had other information to base their opinion on apart from the information provided in the survey. The remaining respondents formed their opinion using the CCS information provided and their own values, beliefs, knowledge, ways of thinking, and other life experiences.

Generally the higher participants self-rated their knowledge, the more concrete their opinions were. This was apparent in the portion of neutral opinion decreased as the CCS knowledge of the participants increased. This tendency appears especially clearly in the instance of CCS “in your country”, as the portion of supportive opinion increased as CCS knowledge of participants increased (except of those who already knew a lot about CCS). However, in terms of opinions about CCS “offshore”, the tendency was weak. This implies it is harder to form opinions about “CCS offshore” compared with “CCS in your country” by gaining knowledge about CCS provided in this research.

To investigate factors related to the formation of first opinions on CCS implementation, we conducted three regression analyses using opinions on the implementation of the three different types of CCS as dependent variables and characteristics of participants as covariates. Table 17 in Appendix F shows the results of the best regression. Results showed that the adjusted R-squared (0.134 – 0.173) indicates the regressions did not fully explain the factors that influence respondents’ opinion formation about CCS implementation. This result implies that many other factors influence a person’s willingness or support for letting a CCS project proceed.

Second assessment

After additional information was provided, we asked the same set of questions in the second assessment regarding implementation of CCS. Figure 13**Error! Reference source not found.** shows the percentage breakdown of opinions participants stated for each of the three implementation questions. The majority of respondents (66% for CCS “in your country”, 69% for CCS “in your neighbourhood”, and 67% for CCS “offshore”) maintained the same opinions for each question across the two assessments. Those who changed opinions moved in either a positive or negative direction; but across the three questions more participants became increasingly negative rather than positive. As a result, in the second assessment the portion of neutral opinions decreased considerably; and the level of negative opinion increased significantly compared with the first assessment.

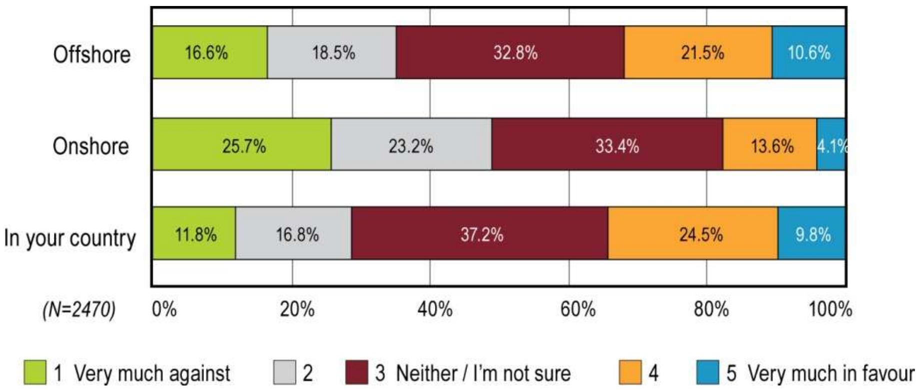

Figure 13: Opinion on CCS implementation by all participants (Second assessment)

Note: For clarification, ‘onshore’ in the graph refers to ‘in your neighbourhood’ proximity

Influence of information on CCS implementation acceptance

We conducted an ANOVA to look for changes between the first and second assessments, testing the differences among the provided information packages. Results are in

Table 18, Appendix F. Furthermore, to find the effect of each piece of information in the information packages we conducted regression analyses using importance measurements of the pieces of information as independent variables and changes of opinions on CCS implementations between the first and second assessments as dependent variables (see

Table 19, Appendix F). We found that generally the information condition influenced opinion on CCS implementation negatively, except for the condition providing CO_2 characteristics and the control condition. We found significant but weak influences of information packages and pieces of information[11] on the opinions on CCS implementations via theses analyses as follows.

Information on CO_2's properties was found to affect opinions on implementation in the respondent's country (beta 0.07, $p<0.01$). Information on natural phenomena also affected opinions on CCS in one's country, which can be explained by a combination effect of a negatively significant covariate of information on Mount Mammoth (beta -0.21, $p<0.01$) and a positively significant covariate of information that people experience health benefits through bathing in water with high CO_2 concentrations in some hot springs) (beta 0.14, $p<0.01$). We also found the effects of information regarding CO_2 behaviour in CCS were explained by information on induced seismicity due to CCS (beta -0.05, $p<0.01$). Similar effects were found in the case of attitudes towards CCS implementation in one's neighbourhood and offshore.

Influence of all factors on CCS implementation acceptance

To investigate factors related to the formation of second opinions on CCS implementation, we conducted regression analyses using opinions on the implementation of three different types of CCS as dependent variables and participants' thoughts, knowledge and characteristics as stated in the questionnaire as covariates. The overall results are summarised in Table 5.

Overall, the results showed:

- Provided information packages describing CO_2's characteristics had a positive influence on opinions of all types of CCS implementations, especially information on CO_2's properties and sources.
- Provided information packages describing natural phenomena including CO_2 had a negative influence on acceptance of CCS implementation in any location, especially information on Mt. Mammoth and on the paint factory accident[12]; however, information on hot springs provide positive effects on opinions.
- Provided information packages describing CO_2's behaviour during CCS had a negative influence on acceptance of CCS implementation in any location except for offshore CCS. Information regarding micro-earthquakes and the possibility of CO_2 leakage through cracks in caprock had a particularly strong negative influence, while information regarding existing CO_2 transportation activity provided positive effects.

Table 5: Effect of information provision on acceptance of CCS implementation

Provided info package	DV	ImplementCountry	ImplementOnshore	ImplementOffshore

[11] It is important to note that we found high collinearity among covariates. In information package B there is relatively high collinearity between "InfoMtMammonth" and "InfoNyos". Therefore, "InfoNyos" also provided the similar effects as "InfoMtMammonth". In information package C, we also found high collinearity between "InfoCapture" (information on current industrial practice of CO2 capture), InfoTransport" (information on current industrial practice of CO_2 transport) and "InfoCauseEarthquake". We argue that these pieces of information can be substituted for each other in this analysis.

[12] In Moenchengladbach, Germany, a paint factory experienced a fire. One hundred and seven people were injured by a defect in the CO_2 extinguisher system of the factory, and thirteen people were treated in a hospital due to the CO_2-enriched gas released from the factory. The nearby area was sealed off for a time, and the residents were ordered to shut their windows and go to higher floors.

			DF		DF		DF	
InfoA CO_2 characteristics	ANOVA	F	13.537		7.168		7.485	
		P-value	0.000		0.007		0.006	
	Regression	Significant variables	InfoProperty	0.072	InfoProperty	0.060	InfoPlace	0.071
InfoB CO_2 impact & natural phenomena	ANOVA	F	6.623		7.584		7.826	
		P-value	0.010		0.006		0.005	
	Regression	Significant variables	InfoHotSpring	0.142	InfoHotSpring	0.132	InfoHotSpring	0.224
			Info MtMammoth	-0.212	Info MtMammoth	-0.192	Info PaintFactory	-0.274
InfoC CO_2 behaviour in CCS	ANOVA	F	4.261		4.664		2.360	
		P-value	0.039		0.031		0.125	
	Regression	Significant variables	InfoCause Earthquake	-0.056	InfoTransport	0.147		
					InfoLeak Cracks	-0.196		
InfoD CCS information*	ANOVA	F	0.101		2.540		1.142	
		P-value	0.751		0.111		0.285	
	Regression	Significant variables					InfoCO_2andCC	0.064
CCS Consequence (order effects)	ANOVA	F	2.709		1.775		8.544	
		P-value	0.100		0.183		0.003	
	Regression	Significant variables	CCS Consequence	-0.056			CCS Consequence	-0.089
Adjusted R-squared			0.017		0.015		0.019	

Effect of provided information package is positive and significant (p<0.05 or p<0.01) in ANOVA*

Effect of provided information package is negative and significant (p<0.05 or p<0.01) in ANOVA*

Effect of provided piece of information is positive and significant (p<0.05 or p<0.01) in regression

Effect of provided piece of information is negative and significant (p<0.05 or p<0.01) in regression

* Whether positive or negative is judged by sign of mean change in each variable

Table 20 in Appendix F shows the results of the best regression that relates the effects of CO_2 knowledge, CO_2 impressions, misperception/understanding of CCS, and respondents' demographics to CCS implementation acceptance. The model fits (the adjusted R-squares) were much increased when compared with the regression on the first assessments.

As before, refusing increases in tax to address climate change had a negative effect on preferences to implement CCS in one's country, in one's neighbourhood, and offshore (beta -0.04, -0.06, and -0.05, respectively; $p<0.01$). Understanding how CO_2 affects the climate had a positive effect on attitudes towards CCS implementation in one's country (beta 0.05, $p<0.01$) and CCS implementation offshore (beta 0.04, $p<0.01$).

Larger effects were found to result from beliefs that CCS poses too many risks for human health (negative effect, beta -0.29, -0.22, -0.04, $p < 0.2$), and that CCS is essential to mitigate climate change (positive effect, beta 0.29, 0.2, 0.24, $p<0.01$). In addition, the belief that CO_2 leakage from underground storage can be measured and monitored properly by available technology, and that the experts involved in CCS implementation know enough about CO_2 storage to safely implement this technology consistently influenced opinions positively at the 1% significance level.

The impression from the second assessment that CO_2 is safe provided a positive effect for CCS implementation in one's country (beta 0.06, $p<0.01$), CCS in one's neighbourhood (beta 0.09, $p<0.01$) and CCS offshore (beta 0.06, $p<0.01$). Similarly, a positive impression about CO_2 from the second assessment provided a positive effect for CCS implementation offshore (beta 0.07, $p<0.01$).

Implementation opinion variation across countries

Finally, effects appeared which were not explained by individual characteristics or answers in the questionnaire but by country of residence. Dutch respondents were more negative toward CCS implementation in their country (beta -0.05, $p<0.01$) in contrast to respondents from other countries.

In addition, Japanese survey respondents were more negative toward CCS implementation offshore (beta -0.17, $p<0.01$) compared to respondents from other countries. This result could be partially explained by the geographical proximity of offshore CCS to the Japanese mainland. Most Japanese residents live in coastal areas and, as reported in the focus groups, respondents did raise concerns about the influence of offshore CCS on their environment as a reason to oppose this option.

Part IV Discussion

8 Discussion

This international research project aimed to determine how individuals across Australia, the Netherlands, and Japan understand CO_2's properties, and to examine the influence of that knowledge on their perceptions of CO_2 and CCS. It additionally aimed to investigate how providing information about the underlying properties and characteristics of CO_2 influences individual attitudes towards CCS.

8.1 How do people understand and perceive CO_2?

Similar to previous findings (e.g. Itaoka et al., 2007; Paukovic et al., 2011; Wallquist, Visschers, et al., 2009; Whitmarsh, Seyfang, et al., 2011) the current research showed that CO_2 was moderately to poorly understood by many participants. Survey respondents were somewhat familiar with CO_2's basic properties (e.g. it occurs naturally, is contained in air, and is absorbed by plants); however, over 50% were uncertain whether CO_2 was soluble in water or degradable. Respondents were generally aware of CO_2's sources but unsure of its uses, except for Australians, who were most knowledgeable on the subject (a result that may be related to the over representation of highly educated survey panel participants.) Respondents were generally confused regarding CO_2's effects, with many believing that it harms the ozone layer, particularly Japanese respondents. A large proportion was uncertain whether CO_2 affects humans in the same way as carbon monoxide and soot. Overall, initial perceptions of CO_2 were that it was slightly negative, dangerous, and dirty, but slightly useful, though most participants did not provide a definitive response.

8.1.1 WHAT INFLUENCES THESE CO_2 PERCEPTIONS?

A number of factors were found to influence initial impressions of CO_2. Belief in global warming and knowledge that CO_2 is emitted from natural gas or coal-fired power stations was related to a negative perception of CO_2. Also, the prior belief that CO_2 has the same effects on human health as air pollutants such as soot had the strongest influence on the perception of CO_2 as "dirty" and "dangerous." Perceptions about CO_2's usefulness were most strongly influenced by knowledge about its role in plant growth. Country of residence also played a role: Japanese and Dutch respondents were more negative about CO_2 and perceived it as dirtier and less useful than did Australian respondents. Respondents in Japan were found to perceive CO_2 as safer, compared to those in Australia or the Netherlands. Dutch respondents had the most consistently unfavourable perceptions of CO_2.

8.1.2 ARE THERE INTERNATIONAL DIFFERENCES IN BROADER CLIAME CHANGE BELEIFS?

The variation in CO_2 perceptions occurs against a backdrop of varied attitudes towards climate change and energy topics. Belief in climate change and the need for immediate action to address it was significantly higher in Japan than in Australia and the Netherlands. Respondents in the Netherlands were much less convinced or concerned about climate change and related issues, while Japanese respondents held a greater belief in climate change, were more concerned over the depletion of fossil fuels, and had higher levels of support for urgent action and for renewable energy use. Respondents in Australia were moderately concerned about climate change and moderately supportive of action against climate change and of promoting renewables.

Respondents across all countries tended to agree that it is important to accept some risks related to a new technology, and that they were unwilling to pay more taxes to address climate change.

8.2 How do people understand and perceive CCS?

The current findings show that awareness of CCS was low amongst survey respondents, with over half (53%) indicating that they had not heard of the technology. These results are in accordance with previous studies in Australia (Ashworth et al., 2009a), Japan (Itaoka et al,2009; Itaoka, Saito & Akai, 2005) and The Netherlands (de Best-Waldhober et al. 2009; de Coninck & Huijts, 2005) showing that the general public has low levels of knowledge about CCS. Awareness does seem to have increased in recent years though, especially in the Netherlands, with 64% stating to have not heard about CCS in 2005, 43% in 2008 (de Best-Waldhober and Daamen, 2011) and 34% in this study. This last result is similar to findings in a study done a few months earlier in the Netherlands, where 35% of respondents indicated that they had not heard of the technology (Paukovic et al, 2011). This study provided a reasonable explanation for the recent rise in awareness in the Netherlands as well, with results showing that 95% of respondents that stated to have heard quite a bit about CCS, also indicated to have heard about the plans for implementation of a CCS project in the town of Barendrecht. Combining this result with the fact that the Netherlands is the only of the three countries where there was such attention for the protest against a CCS demonstration project, it seems logical to conclude that the bigger increase in awareness observed in the Netherlands is caused by the attention for the CCS demonstration project in Barendrecht.

One quarter of all respondents indicated they had heard of the technology but did not know what it was, which highlights the gap between public awareness and actual knowledge of CCS. Respondents with higher awareness and self-reported knowledge of CCS had more pronounced opinions about it, and tended to perceive it more positively as somewhat useful. In contrast, having heard of CCS but having no knowledge of it did not lead to strong opinions. This is a similar finding to that of existing risk communications research regarding opinions on unfamiliar topics, as described by Ashworth and colleagues (2009). It may show that individuals with a less-formed opinion or less self-rated knowledge have the potential to be influenced, particularly by processes of engagement rather than by one-way provision of information (Ashworth et al., 2009a).

Respondents held a number of misperceptions regarding the likelihood of CCS consequences and the effects of CO_2 in CCS. In particular, respondents thought it likely that earthquakes would cause leakage of CO_2, and believed CO_2 was stored in vacant underground chambers. After the technology was explained to respondents, CCS was generally perceived as positive, clean and useful. However, many were uncertain about its safety and maturity. When awareness of CCS was compared with perception of CCS, results showed that respondents had more established and stable views of CCS when they are better informed.

8.2.1 WHAT INFLUENCES THESE CCS PERCEPTIONS?

Several factors appeared to influence these initial impressions. One was the respondents' stated willingness to accept the risk that often accompanies new and emerging technologies; this had a favourable influence on perceptions of CCS as positive, safe, clean and useful. Concerns about the risk of CCS on human health had the strongest negative impact on CCS impressions, demonstrating the importance of risk communications. Demographically, the older age ranges (50 years and older) perceived CCS more favourably, and women perceived CCS less favourably. Impressions of CCS were negatively influenced by concerns over its health risks, while the perception that CCS is an effective climate change mitigation measure positively influenced overall impressions of it. The percentage of the respondents who stated negative opinions seemed to reflect how close the potential CCS implementation sites seemed to be, as had appeared during the discussion in the focus groups.

In accordance with findings of Terwel and colleagues (2009) and Tokushige (2007) the strongest correlation to all CCS perceptions lay in how respondents rated the credibility of information sources. Which information sources participants trusted was correlated with their perceptions of CCS and its implementation options. Trust in public sector organisations such as local governments and UN agencies, as well as in national newspapers, and scientists, had a positive correlation with an accurate understanding of CCS. Trust in national NGOs, local NGOs, friends, and websites was negatively correlated with accurate understandings of CCS. This suggests that members of the public with a poorer understanding of CCS are less likely to trust public sector and scientific sources—highlighting the need to find less formal mechanisms for outreach. The positive effect of the credibility of experts' knowledge demonstrates that it is important for respondents to be able to perceive information sources such as 'developers' or 'scientists' as knowledgeable and competent.

Furthermore, and again echoing Ashworth and colleagues (2009a), opinions were more stable where respondents were better informed. Respondents who had indicated higher levels of awareness and knowledge of CCS were more certain of their opinion in either the favourable or unfavourable direction. Respondents with lower levels of awareness and self-rated knowledge were more uncertain and tended to be slightly favourable towards CCS.

Comprehension of CCS's role as a global warming mitigation strategy exerted one of the strongest influences on the CCS impressions 'positive', 'clean' and 'useful.' This suggests that receiving more background information about CCS and its potential role as a climate change mitigation technology assists in forming favourable opinions about it.

More broadly, previous research has shown that providing information that is considered neutral regarding CCS may in fact lead to a decreased preference or support for CCS implementation (Itaoka et al., 2009). This calls into focus the need to consider other ways to present information, such as processes of small-group engagement (Ashworth et al., 2009b), and other dimensions of communication, such as trust in the information source (Ashworth, et al., 2009a).

8.2.2 WHAT INFLUENCES ACCEPTANCE OF CCS IMPLEMENTATION?

Regarding the implementation of CCS in their country, in their neighbourhood, and offshore in the nearest ocean, many respondents (around 40%) had neutral opinions once they had viewed the basic CCS information and diagram. Respondents were generally more favourable to offshore storage than onshore, although Japanese survey respondents were less favourable towards offshore storage compared to respondents in Australia and the Netherlands.

An understanding of the basic cause and effect of climate change was found to positively influence favourable opinion on the implementation of CCS in the respondents' country and offshore, but not on implementation in the respondent's neighbourhood. Understanding the relationship between CO_2 and climate change was positively correlated to support for the 'in my country' and 'offshore' implementation options, but not the 'in my neighbourhood' option. In the case of this 'onshore' option, the influence of a basic cause-effect understanding of CO_2 and climate change seems to be reduced by perceptions that CCS is dangerous.

Analysis could not fully explain initial opinions regarding CCS implementation; however, key influencing factors included respondents' values and beliefs, a person's tendency to accept technology-related risk, and their level of support for the use of increased taxes to address climate change. Knowledge of both the properties of CO_2 and its uses had varying results in terms of their influence on CCS implementation option perceptions. Knowledge that air contains CO_2 was negatively correlated with support for implementation in one's neighbourhood; while knowledge of the use of CO_2 in fizzy drinks was positively related to all implementation options.

It is also interesting to note that respondents who indicated that they had an awareness of CCS, but limited knowledge of it, were more favourable to the implementation options offered compared to those who had either low or high levels of knowledge about CCS. Perceiving CCS as risky had a substantial negative impact, and perceiving CCS as a necessary climate change mitigation strategy had a substantial positive impact. This conforms with the existing research (Itaoka, Saito, & Akai, 2004) suggesting that levels of awareness of both the risk associated with CCS and its potential benefits largely explain peoples' level of acceptance of CCS technology and implementation.

8.3 How do CO_2 knowledge and perceptions relate to CCS knowledge and perceptions?

Research results strongly suggest that the key factor affecting misperceptions of CCS was misperceptions about CO_2: almost all misperceptions about CO_2 were correlated to misperceptions about CCS. It was found that respondents' level of misunderstanding of CO_2 was related to how risky they perceived CCS to be. Therefore, a person's level of accurate understanding of CO_2 characteristics directly influences his or her understanding of CCS as a technology. As would then be expected, provision of information about CO_2 properties was positively correlated to the respondents' displaying a more correct understanding of CCS (see section 5.3.1 for additional discussion of the influence of information).

As with knowledge, impressions of CO_2 were reflected in overall impressions of CCS. For example, respondents who saw CO_2 as useful strongly tended to perceive CCS as also more useful. Perceiving CO_2 as useful and dangerous led to the belief that CCS was also useful and dangerous. In fact, perceiving CO_2 as dangerous was one of the strongest predictors of perceiving CCS as dangerous. Knowledge of where CO_2 comes from influenced perceptions of whether CCS was a useful and mature technology. As may have been expected, the belief that CO_2 is related to climate change resulted in perceptions of CCS as more useful.

Interestingly, after respondents received a short introduction to CCS, their perceptions of the technology also played a role in determining their perceptions of CO_2—an effect in the reverse direction from the main focus of this paper. For example, those who received information about CO_2's behaviour during CCS perceived the gas as less useful, but not more dangerous. This is interesting from the perspective of communicating about CO_2 and CCS because it shows that CCS communication efforts may affect public opinion towards CO_2, as well as vice versa.

8.3.1 WHAT ARE THE EFFECTS OF PROVIDING INFORMATION?

Effects on CO_2 perceptions

After receiving information packages on CCS, participants gave a similar pattern of responses on how they perceived CO_2, but more participants had formed an opinion either towards a more positive or a more negative opinion. The information packages had relatively straightforward influences. Respondents who received information about the characteristics and effects of CO_2 became generally more positive about the gas, tending to report seeing it as more useful, clean, and safe. The analysis provided some surprising outcomes as well. Those respondents who received information about natural phenomena involving CO_2 (e.g., the Lake Nyos incident) perceived CO_2 as more dangerous, but did not report that they had a more negative impression of it. Essentially, respondents who had no specific opinions on CCS initially moved towards a more positive or negative opinion depending on the information provided. This highlights the importance of receiving reliable and balanced information in order to be able to form an opinion. It also means that people do not automatically become more positive about the technology if they know more about it or understand it better, but their opinions become more informed and more stable.

Effects on CCS perceptions

Most respondents maintained the same opinion of CCS after the provision of information about it. Those who did change their opinions tended to perceive CCS as less positive, less clean, and less safe. Despite the fact that misperceptions of CCS relate to misperceptions of CO_2, little change occurred in CCS perceptions when respondents were provided with information about CO_2's characteristics, natural phenomena relating to CO_2, CO_2 behaviour during CCS, or several of these pieces of information. Three slight changes did occur:

- Information on CO_2 characteristics (i.e., properties and chemistry) increased the perception of CCS as a mature technology.
- Perceptions of safety were damaged by information on CO_2 natural phenomena, particularly Mt Mammoth.
- Information about the behaviour of CO_2 in CCS (particularly about induced seismicity) negatively influenced impressions of CCS as positive, clean (particularly related to the small chance of CO_2 leakage), and safe (particularly related to topsoil acidification risk).

In instances where changes in perceptions did occur, the type of knowledge presented led to different effects. For example, perceptions of CCS as 'positive', 'clean', 'useful' and 'dangerous' were affected negatively and significantly by the provision of all sets of information. As another example, informing participants of CO_2's behaviour during CCS had mixed effects on perceptions (e.g., transport was viewed more positively, but earthquake risks were viewed more negatively); these effects may have cancelled each other out. This pattern demonstrates the importance of conveying complete and correct information on CO_2's characteristics, as greater understanding could mitigate issues that may arise when respondents receive incomplete information about CCS, such as by means of a single negative anecdote.

Effects on attitudes towards implementation

The majority of respondents did not change their opinions on CCS implementation between the first and second assessment. The influence of respondents' demographics was also somewhat consistent between the two assessments. Respondents who had not changed their opinions were found to have greater pre-existing knowledge of CO_2's properties and characteristics; as such, they may have tended to form their opinions based on their own knowledge and experience rather than the information that was provided to them as part of the survey. Respondents' perceptions regarding the risks and necessity of CCS were found to have the greatest influence on overall opinions on CCS implementation: the perception that CCS entailed too many risks to human health had a negative effect, while the belief that CCS is essential to mitigate climate change positively influenced opinions on CCS implementation.

In general, the effects of information provision on respondent opinions of CCS implementation were weak but consistent. It was noted that there was high collinearity among the covariates between the pieces of information in package B (i.e., regarding Lake Nyos, Japanese hot springs, the paint factory incident, Mt. Mammoth, and natural CO_2 storage domes) and package C (i.e., regarding the behaviour of CO_2 in CCS). The Mt Mammoth effects stood out particularly; however, the paint factory accident information and the Lake Nyos information led to more or less the same effects. Information on induced seismicity due to CCS was also seen as important. The information on CO_2's behaviour in capture and transport provided a positive effect on CCS implementation perceptions, and information on the possibility of CO_2 leakage via cracks had a negative influence.

Generally, as knowledge about CO_2 increased, the tendency towards definitive/ pronounced (i.e. non-neutral) opinions about CCS implementation also increased, although in terms of opinions about CCS 'offshore', the tendency was weak. This may imply that it is harder to form opinions about CCS 'offshore' compared with CCS 'in your country' or 'in your neighbourhood' through the information about CCS that was provided in this research. It may be that respondents asked to provide an opinion about offshore implementation feel they are being asked to speak about something that is not meaningful to them at the moment. However, it is understandable that it may have been difficult for respondents to change opinions substantially by learning through information provision in such a short space of time as occurred in the survey, regardless of the content of the information provided.

8.4 Summary

In summary, respondents were found to have reasonable general knowledge of CO_2 but poor knowledge of some of its scientific dimensions such as flammability and health effects, giving them the opportunity to misunderstand and perceive it incorrectly. Their misperceptions of CO_2 were directly related to their misperceptions of CCS, yet only indirectly related to their opinion on CCS implementation. Influences of information provision were statistically significant but weak. Due to the survey's large sample size, these influences could be distinguished; they break down among the general information categories as follows: information on CO_2 natural phenomena and CO_2 behaviour in CCS had a negative effect, while information on CO_2 characteristics (specifically properties and chemistry) had a favourable effect on CCS perceptions and often mitigated the negative effects of the other information. The next chapter comments on how to act on these findings.

Part V Conclusion and Recommendations

9 Conclusion and Recommendations

9.1 Conclusion

Government agencies, funders, and international energy organisations have paid a good deal of attention to CCS as part of a technology portfolio for mitigating climate change. As citizens from all backgrounds become involved in the larger social conversation around CCS, they are currently assessing, judging, and forming opinions of this technology. These opinions emerge at the intersection of many societal variables, including each person's values and beliefs regarding carbon and climate, as well as the person's knowledge of CCS technology itself. Beyond these obvious dependencies lies a less obvious influence on opinions of CCS: public knowledge and perceptions of the gas itself, CO_2.

Our research in three countries identified variations in values, beliefs, knowledge, and perceptions of CO_2. Beyond gathering this data, we attempted to relate individuals' values and beliefs, knowledge, and perceptions around CO_2, and knowledge of CCS to whether individuals formed more or less favourable opinions of this technology.

Overall, participants demonstrated moderate to low levels of knowledge of CO_2's properties, uses, and effects. Japanese respondents demonstrated the highest levels of correct knowledge, and confidence about that knowledge, regarding CO_2's properties and sources, while respondents from the Netherlands displayed the lowest levels. While CO_2's uses were generally not well known, the Australian respondents (comprising a slightly more educated sample than the general public) had the greatest familiarity with its potential uses. A general level of confusion surrounds CO_2's effects. In particular, it was frequently misperceived as an ozone-depleting gas with the same effect as air pollutants such as soot.

This lack of knowledge of CO_2 has important implications for climate change and CCS communicators. A low level of knowledge about CO_2 and its relationship with climate change is correlated with climate change scepticism. This is particularly relevant for climate change scepticism in the Netherlands (de Best-Waldhober, et al., 2011; Upham & Roberts, 2011), whose respondents recorded the lowest level of knowledge about CO_2 and the highest level of uncertainty about the reality of climate change during this study.

Research results included many other intriguing patterns, as described in the previous chapter, which lead to several recommendations for members of the CCS industry and community. Essentially, knowledge and perceptions of CO_2 were found to be an important factor correlating with attitudes towards CO_2. This outcome argues for paying increased attention to communicating the nature, properties, sources, uses, and effects of CO_2 while engaging public stakeholders in education and outreach regarding CCS.

9.2 Recommendations

9.2.1 NEED FOR EFFORTS TO PROMOTE DIALOGUE AND UNDERSTANDING ABOUT CCS TO INCORPORATE INFORMATION ON CO_2

The demonstration of the limited knowledge base of respondents in this research highlights the need for communicators to focus on the education of the general public about CO_2's properties, sources, uses and effects, and especially the basic cause-effect relationship between CO_2 levels and climate change. Prior to receiving information, the majority of respondents did not provide a definitive response when asked to scale and report their perceptions. This may demonstrate that a lack of knowledge about CO_2 is associated with an absence of clarity and certainty about how to perceive it. Therefore opportunity and motivation exists for communicators to explain the nature and properties of CO_2.

9.2.2 NEED FOR BALANCED AND COMPLETE INFORMATION ONO CO_2'S PROPERTIES

Particularly important to communicate are CO_2's effects on humans and the environment (e.g., potential for soot-like effects and toxicity.) Also important are the issues of presumed risk and natural hazard issues (e.g., earthquakes.) The strongest influence on CCS perceptions was exerted by concerns of the risk of CCS on human health, which had a negative impact on CCS impressions. This result shows quantitatively that risk communication considerations are one of the biggest issues to be addressed in developing public understanding of CCS.

9.2.3 NEED TO ADDRESS TOPICS DEEMED IMPORTANT BY RESPONDENTS

The variation of reactions, anxieties, and beliefs amongst respondents highlights the importance of accounting for these in communication and education efforts. Essentially, in addition to first informing on the properties of CO_2, communications about CCS must also account for a wide range of typical misperceptions regarding CO_2. It is worth noting that perceiving CO_2 as useful makes respondents perceive CCS as more useful. The same can be said about perceiving CO_2 as more dangerous; it also makes respondents perceive CCS as more dangerous. The fact that respondents considered descriptions of CO_2's natural locations and its behaviour in CCS to be important supported the researchers' choice to include basic and wide-ranging information in the survey, and should similarly influence future communication decisions.

9.2.4 NEED FOR CARE IN DESCRIBING CO_2 NATURAL PHENOMENA

It is important to present open and transparent information, such as on Lake Nyos and Mt Mammoth (both the positive and negative sides). The information on "CO_2 natural phenomena" (especially on Mt Mammoth) could change CCS impressions in a negative direction, because some respondents might have increased concerns about the risks and dangers of CCS by perceiving the information (such as that provided about Lake Nyos or Mt Mammoth) as an analogue of CO_2 leakage in CCS (as was seen in the interviews and focus groups). Therefore more detailed explanations of the differences between an event such as Mt Mammoth and the potential consequences of CO_2 leakage in CCS are required.

9.2.5 NEED FOR CARE IN ADDRESSING CO_2'S BEHAVIOUR IN CCS

The effects of the information on CO_2 behaviour in CCS were mixed between positive and negative, and sometimes cancelled each other out. For instance, the information on "CO_2 characteristics" was shown to mitigate the negative impact on this scale caused by the information "CO_2 natural phenomena." It is important to convey the correct information on CO_2 characteristics because the understanding of CO_2 characteristics could mitigate misunderstandings that arise when respondents receive any incomplete or indirect information about CCS.

9.2.6 NEED FOR ADDITIONAL BASIC INFORMATION ON CLIMATE CHANGE, CCS AND THEIR RELATIONSHIP TO CO_2 EMISSIONS

Understanding of the effectiveness of CCS as global warming reduction measure was one of the strongest positive factors that influenced the CCS impressions "Positive", "Clean", and "Useful." This suggests that respondents should receive more background information about CCS and its role as a climate change mitigation technology in order to form an opinion about CCS. This study also demonstrated a significant gap between "awareness" and "knowledge," similarly to what has been previously shown by Ashworth, Beath, Boughen, & Littleboy (2005). Results show that awareness does not directly imply knowledge, as in all three cultural settings approximately one quarter of respondents indicated having heard about CCS, but not really knowing what it was. This knowledge-awareness gap poses an issue for communicating about CCS, as the results also demonstrate that knowledge about CCS plays a key role in forming people's opinions about the technology: mere awareness would seemingly lead to a different opinion than knowledge. This result highlights the importance of education and the provision of reliable and balanced information in CCS communication strategies.

9.2.7 NEED FOR ADDITIONAL CCS EDUCATION AND OUTREACH CAMPAIGNS THROUGH LESS-FORMAL MECHANISMS

Analysis showed a strong relationship between participants' tendency to believe in the credibility of certain information sources and their knowledge of CCS topics. Trust in friends, websites, and national and local NGOs was negatively correlated with correct understanding of CCS. These sources may be labelled "less formal" in contrast to public sector organisations, local government, national newspapers, and scientists. The correlation between trust in informal sources and poorer understanding of CCS suggests that the people with the poorest understanding of CCS may also be least likely to trust information and education by government, scientists, and other formal authorities regarding it. Therefore, sole reliance on the formal information sources (i.e., public sector organisations, local government, national newspapers, and scientists) may not reach the people with the poorest understanding of CCS. Alternative means should be adopted.

Part VI Appendices and References

Appendix A Interview Structure

Topic 1. Current knowledge and perceptions of CO_2 and CCS

Knowledge about CO_2

Q: Have you ever heard the word “carbon dioxide”?

Q: What is carbon dioxide?

Q: Do you know any characteristics of carbon dioxide?

Q: Do you know where carbon dioxide exists?

Use of CO_2

Q: Do you know the intended purposes of carbon dioxide?

Perception of CO_2

Q: Please tell me your images of carbon dioxide.

Q: What do you think about carbon dioxide?

Knowledge on climate change or global warming

Q : Have you ever heard about “climate change” or “global warming”?

Q : Do you know the causes of the climate change / global warming?

Q : Do you know the methods to prevent the climate change / global warming?

Knowledge of CCS

Q : Have you ever heard the words “carbon dioxide capture and storage”, “carbon sequestration”, or “geo-sequestration of carbon dioxide”?

Q : (For people who have heard these words) What do these words mean? What kind of images and understanding do you have about CCS?

Q : (For people who have never heard these words) What kind of images does “carbon capture and storage” invoke? What do you think it is?

Provide Information on CCS <Information sheet A>

Perception of CCS

Q: Please tell me your images of CCS. What do you think about CCS?

Q: Among CO_2 capture, transport, and storage of the CCS, which is the most attractive part?

Q: What do you think about CO_2 capture?

Q: What do you think about CO_2 transport?

Q: What do you think about CO_2 storage?

(In the case of CO_2 storage underground)

(In the case of CO_2 storage under the seabed)

Provide a short questionnaire on knowledge of CO_2’s physical properties

Topic 2. Influence of information provision

Provide information sheet on analogues and commercial commodities that include CO_2 <Information sheet B>

Influences of information on perceptions of CO_2 and CCS

Q: Did your images and understanding about carbon dioxide change?

Q: How did your images and understanding change? Which information changed your images and understanding? And why?

Q: Did your images and understanding about CCS change in general?

Q: Did your images and understanding about CO_2 capture, transport, and storage change?

Q: How did your images and understanding change? Which information changed your images and understanding? And why?

Provide information sheet on CO_2 <Information sheet C>

Influences of information on perception of CO_2 and CCS

Q: Did your images and understanding about carbon dioxide change?

Q: How did your images and understanding change? Which information changed your images and understanding? And why?

Q: Did your images and understanding about CCS change in general?

Q: Did your images and understanding about CO_2 capture, transport, and storage change?

Q: How did your images and understanding change? Which information changed your images and understanding? And why?

Provide information sheet on behaviour of CO_2 in CCS <Information sheet D>

Influences of information on perception of CO_2 and CCS

Q: Did your images and understanding about carbon dioxide change?

Q: How did your images and understanding change? Which information changed your images and understanding? And why?

Q: Did your images and understanding about CCS change in general?

Q: Did your images and understanding about CO_2 capture, transport, and storage change?

Q: How did your images and understanding change? Which information changed your images and understanding? And why?

Information needs on CO_2 / CCS and others

Influences of information on perception of CO_2 and CCS

Q: What kind of information about CO_2 or CCS do you want more?

Q: What would you think if CCS project were planned near your house?

Q: What would you think if CCS project were planned in the closest sea to your residential area?

Respondents' characteristics

Q: Do you sometimes collect scientific information you are interested in? What kind of information sources do you tend to trust? (TV, newspaper, magazine, books Internet etc. Government, scientists, industries, NGO, etc.)

Q: Which issues are you most interested in? Political, economic, social, environmental, educational, etc.

Appendix B Focus Group Design

Current knowledge and perceptions of CO_2 and CCS

Answer questions listed below by filling out questionnaire
Questions on…

Knowledge about CO_2
Perception about CO_2
Knowledge on climate change or global warming
Awareness of CCS

Discuss knowledge and perceptions of CO_2 and CCS

Perception of CCS based on basic information on CCS

Read provided information on CCS and answer questions listed below by filling out questionnaire
Questions on…

Perceptions about CCS (image, concern, pro/con on CCS project planned near your house, etc.)

Discuss perceptions of CCS

Relevance of knowledge and perceptions of CO_2 to perceptions of CCS

Read provided information on CO_2 and CCS
Information on…

Commercial use, transportation, and phenomena of CO_2
Physical property and toxicity of CO_2
CO_2 behaviour in CCS

Answer questions listed below by filling out questionnaire

Q: Suppose CCS is planed near your house, is provided information positive/negative to decide your attitude toward the CCS project?

Q: Is the information important for you?

Pro/Con about CCS project planned near your house
Pro/Con about offshore CCS project planned at a maritime area in your region

Discuss provided information and its importance

Read additional information on CO_2 and CCS
Information on…

Consequences of phenomena of CO_2
Consequences of CO_2 behaviour in CCS
Consequences of CO_2 leaks in CCS

Discuss change of participants' perception on CO_2 and CCS

Information needs on CO_2, CCS, and others

Answer questions listed below by filling out questionnaire

Q: What kind of information about CO_2 or CCS do you want more of?

Answer questions about participants' characteristics by filling out questionnaire

Q: Do you sometime collect scientific information you are interested in? What kind of information source do you tend to trust? (TV, newspaper, magazine, books Internet etc. Government, scientists, industries, NGO, etc.)

Q: Which issues are you most interested in? Political, economic, social, environmental, educational, etc.

Discuss information on CO_2, CCS, and general issues

Appendix C Survey Design

	Question statements	Variable Names
Q1	**Starting with the following statements of opinion about environment or energy issues, please indicate to what extent this statement applies to you.** (Tick the most appropriate number on the scale from 1-5.)	
	I am convinced that climate change (global warming) is happening.	ConvincedGW
	We should promote the use of renewable energy as soon as possible.	Renewable
	I am worried about fossil fuels running out.	FossilFuel
	It is important for our society to accept some risks related to new technologies.	Risk
	Something should be done about climate change (global warming) now.	DoForGW
	I refuse to pay more tax to address climate change (global warming).	MoreTax
Q2	**Here you are presented with statements about possible characteristics of CO_2. Please indicate how sure you are about the truth of each statement.** Tick the most appropriate number on the scale from 1-5. If you do not know or are not sure of the answer you can choose option 3.	
	CO_2 is lighter than air.	Lighter
	CO_2 occurs naturally.	Naturally
	CO_2 is flammable.	Flammable
	CO_2 is soluble in water.	Soluble
	The air around us contains CO_2.	AirContain
	It is easy to break down CO_2.	EasyBD
Q3	**Here you are presented with statements about possible effects of CO_2. Please indicate how sure you are about the truth of each statement.** Tick the most appropriate number on the scale from 1-5. If you do not know or are not sure of the answer you can choose option 3.	
	Plants and trees need CO_2 to grow.	PlantNeed
	CO_2 influences the climate.	Climate
	CO_2 harms the ozone layer.	Ozone
	CO_2 has the same effect on humans as CO (carbon monoxide).	CO
	CO_2 in high concentrations is toxic for the human body.	Toxic
	CO_2 affects human health in the same way as air pollution substances such as soot.	Soot
Q4	**Here you are presented with statements about possible sources and absorbents of CO_2. Please indicate how sure you are about the truth of each statement.** Tick the most appropriate number on the scale from 1-5. If you do not know or are not sure of the answer you can choose option 3.	
	CO_2 is released during electricity production from power plants using natural gas or coal.	PowerPlant
	The human body creates CO_2.	Human
	CO_2 is absorbed by plants and trees.	PlantAbsorb
	CO_2 is absorbed by oceans.	Ocean
	Naturally occurring CO_2 has a different chemical structure to industrially occurring CO_2.	DifferentSubstance

	Question statements	Variable Names
Q5	**Here you are presented with statements about possible uses of CO_2. Please indicate how sure you are about the truth of each statement.** Tick the most appropriate number on the scale from 1-5. If you do not know the answer you can choose answer option 3.	
	CO_2 is used to make drinks fizzy e.g. cola and soda.	Cola
	Extra CO_2 is put into the air in some greenhouses to help plants grow.	Greenhouse
	CO_2 is used in some fire extinguishers.	FireExtinguisher
	CO_2 is used to make tyres.	Tyre
	CO_2 emissions from industry are much higher than CO_2 inputs into industry.	InputInd
Q6	**Next there are several opposing adjectives about CO_2. Please choose the adjective that most closely reflects your opinion of CO_2 by circling the most appropriate dot on the scales below. The closer your answer is to one of the adjectives, the more it reflects your opinion.**	
	My current impression of CO_2 is Positive/Negative.	CO_2Positive1
	My current impression of CO_2 is Clean/Dirty.	CO_2Clean1
	My current impression of CO_2 is Useful/Useless.	CO_2Useful1
	My current impression of CO_2 is Dangerous/Safe.	CO_2Dangerous1
Q7	**Have you heard about a new technology called Carbon dioxide Capture and Storage, often referred to as CO_2 capture and storage, before participating in this survey?** Tick one box.	Know
Q8	**Next there are several opposing adjectives about CO_2 Capture and Storage. Please choose the adjective that most closely reflects your view of CO_2 Capture and Storage by circling the most appropriate dot on the scales below. The closer your answer is to one of the adjectives, the more it reflects your opinion.**	
	My current impression of CO_2 capture and storage is Positive/Negative.	CCSPositive1
	My current impression of CO_2 capture and storage is Clean/Dirty.	CCSClean1
	My current impression of CO_2 capture and storage is Useful/Useless.	CCSUseful1
	My current impression of CO_2 capture and storage is Dangerous/Safe.	CCSDangerous1
	My current impression of CO_2 capture and storage is Mature/Developing technology.	CCSMature1
Q9	**Implementation**	
	What is your opinion on implementing CO_2 capture and storage in YOUR COUNTRY? Please tick the most appropriate number.	ImplementCountry1
	What is your opinion on implementing onshore CO_2 capture and storage in your neighbourhood? Please tick the most appropriate number.	ImplementOnshore1
	What is your opinion on implementing offshore CO_2 capture and storage in the sub-seabed off YOUR COUNTRY's shores? Please tick the most appropriate number.	ImplementOffshore1
A	**Please read the following information on the characteristics of CO_2. For each set of statements, please consider how important this information is to you in order to form an opinion about CO_2 Capture and Storage. Please tick the most appropriate number.**	
	Carbon dioxide (CO_2) consists of one carbon atom and two oxygen atoms bound together. It is mainly produced by burning carbon-containing fuels.	InfoChemistry

<table>
<tr><th></th><th>Question statements</th><th>Variable Names</th></tr>
<tr><td>A</td><td>Properties:
Colourless
Odourless
Heavier than air, therefore accumulates in low lying areas
Non-flammable
Non-explosive at normal pressure
Water-soluble</td><td>InfoProperty</td></tr>
<tr><td></td><td>Causes 'greenhouse effect' in atmosphere. Greenhouse gases in our atmosphere make sure the sun's warmth on earth does not immediately escape out to space. This 'greenhouse effect' provides a habitable climate for plants, animals and humans.</td><td>InfoGHeffect</td></tr>
<tr><td></td><td>The toxicity of CO_2 depends on its concentration in the atmosphere. Please read the following table which lists indicative physical effects of increasing CO_2 concentrations.
<table>
<tr><th>Concentration of CO_2 (%)</th><th>Time of exposure to onset (minutes)</th><th>Symptoms</th><th>Example of concentration</th></tr>
<tr><td>0.04%</td><td>Prolonged</td><td>None</td><td>Atmospheric concentration</td></tr>
<tr><td>0.1%</td><td>Prolonged</td><td>None</td><td>Concentration in some hot springs</td></tr>
<tr><td>1%</td><td>Prolonged</td><td>Drowsiness</td><td>Concentration in a closed room full of people</td></tr>
<tr><td>2–6%</td><td>5-30</td><td>Heavier or faster breathing
Headache, dizziness, chills and decrease in sensation</td><td>Breath from humans (100 times atmospheric concentration)</td></tr>
<tr><td>6–10%</td><td>5-60</td><td>Dim vision, tremors and loss of consciousness (risk of death)</td><td></td></tr>
</table></td><td>InfoToxicity</td></tr>
<tr><td></td><td>Places where CO_2 exists
Atmosphere
Breath from humans
Forests
Oceans
Underground in oil and gas fields and magma chambers from volcanoes</td><td>InfoPlace</td></tr>
<tr><td></td><td>Uses of CO_2
CO_2 is used to make drinks fizzy e.g. cola and soda
Extra CO_2 is put in the air in greenhouses to help plants grow
CO_2 is used in some fire extinguishers</td><td>InfoUse</td></tr>
</table>

	Question statements	Variable Names
B	Please read the following information on the impacts of CO_2. Please consider how important this information is to you in order to form an opinion about CO_2 capture and storage. Please tick the most appropriate number.	
	Lake Nyos is a crater lake in the Northwest Region of Cameroon, containing large amounts of CO_2 from volcanic activity. In 1986 a large cloud of CO_2 was emitted suddenly and became trapped in the valley, suffocating 1,700 people and 3,500 livestock in nearby villages.	InfoNyos
	At some hot springs such as Nagayu in Japan and Bad Nauheim in Germany, people experience health benefits such as good blood circulation through bathing in water with high CO_2 concentrations (about 1%).	InfoHotSpring
	In Moenchengladbach, Germany, 107 people were injured (and 13 of those were treated in hospital) when a CO_2 fire extinguisher system of a paint factory malfunctioned and CO_2 was released. The nearby area was sealed off for a time and residents were ordered to shut their windows and go to higher floors.	InfoPaintfactory
	For millions of years, CO_2 has been securely sealed underground in natural underground CO_2 reservoirs. For example, in the USA, CO_2 fields called the Jackson, McElmo, and St. Johns Domes were formed millions of years ago, and together hold $_2$.4 billion tons of CO_2.	InfoDome
	In Mammoth Mountain, USA, a large volume of CO_2 seeping from volcanic activity underground has been killing nearby trees.	InfoMtMammoth
C	In industry the capture and compression of CO_2 is common practice. The risks associated with capturing CO_2 from the production process are well known and managed.	InfoCapture
	The CO_2 can be transported in a gas or liquid form using pipelines across large distances. Leaks in pipelines can occur. There is a small chance the leaked CO_2 will accumulate near the leakage point. The USA has a CO_2 pipeline system over 3000 km long which has been in use for more than 20 years. There have been no accidents involving injuries or death.	InfoTransport
	The injection of liquid-like CO_2 underground can cause micro earthquakes similar to those caused by natural gas extraction.	InfoCauseEarthquake
	The CO_2 will enter the storage in a liquid-like form and will not return to a gaseous form as long as it is exposed to typical pressure and temperature found deep underground. Here it will spread out through tiny holes in the rock formation.	InfoLiquidLike
	Underground, liquid-like CO_2 may affect microbial populations which are important for ecosystem stability, affect nutrient supply, acidify ground water and affect the movement of metals and/or other contaminants.	InfoUnderground
	If CO_2 leaks from the storage or injection point into the surrounding soil, there is a small chance it might acidify topsoil and/or impact groundwater and possibly drinking water.	InfoLeakSoil
	If liquid-like CO_2 is stored appropriately, there is a very small chance that small quantities of it would leak through poorly sealed wells, tears and cracks in the caprock layer of the underground storage.	InfoLeakCracks

	Question statements	Variable Names
D	Carbon dioxide, or CO_2, is one of the green house gases. Concentrations of CO_2 in the air are increased, which is said to be one of the main causes of climate change. Many countries, Australia included, consider it very important to reduce CO_2 emissions. One way to reduce CO_2 emissions is CO_2 capture and storage.	InfoCO2andCC
	There are three main steps to successful CO_2 capture and storage. 1) The first step is to capture and separate the CO_2 from other gases, either before or after the fuel, such as coal or natural gas, is burned. 2) The second step is to transport the captured CO_2 to a storage location. 3) The final step is storage. The aim is to store the CO_2 underground, virtually permanently. Storage involves injecting liquid-like CO_2 into rock about 1,000 m below the Earth's surface. Here it will not return to a gaseous form while exposed to typical pressure and temperature found at this depth underground. A large amount of stored CO_2 could be trapped underground. Depleted oil and gas reservoirs provide one possibility for long-term storage and another is in geological formations called saline aquifers (i.e. rock formations filled with saline water).	InfoWhatCCS
	CO_2 capture and storage technology can either be designed into new power plants or fitted onto existing older power plants. New power plants with CO_2 capture and storage technology can reduce CO_2 emissions by approximately 80-90% but they use about 25% extra energy and require additional equipment compared to older conventional power stations.	InfoExtraEnergy
Q10	**Next we repeat the opposing adjectives about CO_2. Please choose the adjective that most closely reflects your opinion of CO_2 by circling the most appropriate dot on the scales below. The closer your answer is to one of the adjectives, the more it reflects your opinion.**	
	My current impression of CO_2 is Positive/Negative.	CO2Positive2
	My current impression of CO_2 is Clean/Dirty.	CO2Clean2
	My current impression of CO_2 is Useful/Useless.	CO2Useful2
	My current impression of CO_2 is Dangerous/Safe.	CO2Dangerous2
Q11	**Next we repeat the opposing adjectives about CO_2 Capture and Storage. Please choose the adjective that most closely reflects your opinion of CO_2 Capture and Storage by circling the most appropriate dot on the scales below. The closer your answer is to one of the adjectives, the more it reflects your opinion.**	
	My current impression of CO_2 capture and storage is Positive/Negative.	CCSPositive2
	My current impression of CO_2 capture and storage is Clean/Dirty.	CCSClean2
	My current impression of CO_2 capture and storage is Useful/Useless.	CCSUseful2
	My current impression of CO_2 capture and storage is Dangerous/Safe.	CCSDangerous2
	My current impression of CO_2 capture and storage is Mature/Developing technology.	CCSMature2
Q12	**Implementation**	
	What is your opinion on implementing CO_2 capture and storage in YOUR COUNTRY? Please tick the most appropriate number.	ImplementCountry2
	What is your opinion on implementing onshore CO_2 capture and storage in your neighbourhood? Please tick the most appropriate number.	ImplementOnshore2
	What is your opinion on implementing offshore CO_2 capture and storage in the sub-seabed off YOUR COUNTRY's shores? Please tick the most appropriate number.	ImplementOffshore2

	Question statements	Variable Names
Q13	**Next you are presented with statements about the potential consequences of CO_2 capture and storage. For each statement, please indicate how likely you think it is that this will be a consequence of CO_2 capture and storage.** Tick the most appropriate number on the scale from 1–5. If you do not know the answer you can choose option 3.	
	The stored CO_2 will move upwards into the atmosphere or the seabed.	MoveAtmosphere
	CO_2 stored underground will affect the soil for plants and crops in the area.	Soil
	In the case of CO_2 leakage from onshore storage, it will affect the human health.	LeakOn
	In the case of CO_2 leakage from offshore storage, it will affect the ocean ecosystem.	LeakOff
	CO_2 stored onshore will eventually flow into the sea.	FlowIntoSea
	Earthquakes can cause CO_2 to leak out of the storage.	EarthquakeLeak
Q14	**Next you are presented with statements about the potential consequences of CO_2 capture and storage which may be true or may be false. For each statement, please indicate how sure you are that this can be a consequence of CO_2 capture and storage.** Tick the most appropriate number on the scale from 1–5. If you do not know the answer you can choose option 3.	
	In the long run stored CO_2 can change into harmful materials through chemical reactions.	ChemicalReact
	The stored CO_2 is expandable and can cause cracks in the caprock of the storage.	Caprock
	The stored CO_2 can catch on fire.	Fire
	Even if the CO_2 remains in the storage it can still influence the surface ecosystem.	Ecosystem
	The CO_2 is stored in a vacant underground chamber, resembling a cave.	Vacant
	The stored CO_2 can emit hazardous radiation.	Radiation
Q15	**Next we repeat the statements about CO_2 capture and storage. Please indicate the extent to which you disagree or agree with each statement.** Tick the most appropriate number on the scale from 1-5. If you do not know the answer you can choose option 3.	
	Some of the stored CO_2 can change into a solid substance.	Solid
	CO_2 leakage from underground storage can be measured and monitored properly by available technology.	MeasureMonitor
	The captured CO_2 should be broken down instead of being stored underground.	BreakDown
	CO_2 capture and storage poses too many risks for human health.	ManyRisk
	CO_2 capture and storage should only be implemented when there is a 100% guarantee that it is safe.	Gurantee
	CO_2 capture and storage is essential to mitigate climate change.	MitigateCC
	Experts involved in CO_2 capture and storage implementation know enough about CO_2 storage to safely implement this technology.	KnowEnough
	I am concerned about what would happen if there were accidents in CO_2 capture and storage.	WhatHappen

	Question statements	Variable Names
Q16	**Which of the sources below would you trust most to give you information about CO_2 capture and storage?** Tick the most appropriate number on the scale from 1-5.	
	National government agencies/organisations	NationalGov
	Local/regional government agencies/organisations	LocalGov
	National television programs that I watch	NationalTV
	National newspapers that I read	NationalPaper
	Local newspapers and television that I read/watch	LocalPaper
	Scientists/researchers	Scientist
	Project developers, energy companies etc	Developer
	National and/or international non-government organisations (NGOs) such as Greenpeace or WWF	NationalNGO
	Local NGOs and/or community groups, residents' associations etc.	LocalNGO
	Friends, neighbours, family	Friend
	Interactive websites (e.g. blogs, wikis etc.)	Website
	United Nations organisations such as the Intergovernmental Panel on Climate Change (IPCC)	UNagency
Q17	**Do you have any professional or recreational activities which relate to CO_2?**	Activity
Q18	**How often do you look up information about the following topics?** Please tick one box for each topic.	
	Nature	Nature
	Environment	Environment
	Physics	Physics
	News	News
	Technology	Technology
	Biology	Biology
	Science	Science
Q19	**Academic background (Completed education)** Tick one of the following.	Academic
Q20	**Your gender and age**	
	Male or Female	MorF
	Age	Age
Q21	**Your postal code**	
Q22	**How clear did you find the information provided?** Please tick the most appropriate number on the scale 1-5.	ClearInfo
Q23	**To what extent did you consider the information provided to be partial or impartial?** Please tick the most appropriate number on the scale 1-5.	ImpartialInfo
Q24	**To what extent did you find the information provided to be trustworthy?** Please tick the most appropriate number on the scale 1-5.	TrustworthyInfo
Q25	**While answering this survey did you take into consideration that this survey is funded by the Global Carbon Capture and Storage Institute (GCCSI)?**	ConsiderFund

Appendix D Participant Demographics

Australian Panel

Survey respondents were Australian residents aged 20 or older. Respondents were selected by stratified random sampling from registrants of a survey company's panel. The panel invited to participate was representative of the demographic characteristics (e.g. gender, age, and educational attainment) of the Australian population. The survey was launched via email to 1,116 residents and completed by 809 respondents, resulting in a response rate of 72.5%. Due to internal error, survey responses were not controlled to derive a completely representative set of participants with respect to educational attainment. Although representative participants had been invited, the actual respondents with bachelor's and postgraduate degrees were 18% and 18%, respectively, adding to 36%, whereas the actual percentage of Australians with either a bachelor's or postgraduate degree is lower (i.e., though gradually rising since 2000, even by 2010 it had only reached 27%) (ABS, 2011).

The table below shows a comparison of the age of Australian survey respondents and the national average. The younger age groups (20–49 years) were under-represented among respondents, while the percentage of respondents 50 years and over was higher than the Australian population.

Table 6: Comparison between Australian survey panel and national average

	Australian Survey Panel (N=809)	***National Average***[a]
Proportion female	53.%	51%
Proportion Age ≤ 29	13%	18%
30 ~ 39	19%	20%
40 ~ 49	18%	20%
50 ~ 59	25%	18%
≥ 60	25%	25%

[a] ABS (2007). *2006 Census Tables: Australia. Cat. No. 2068.0*.

Japanese panel

The Japanese respondents were selected by random sampling of the general public aged 20 or older living in Japan. Sampling proceeded by the random walk method, whereby surveyors started at one address in the area of the sampling point and then randomly selected another map address to find the next participant. The survey's URL was hand delivered to respondents, who filled out the questionnaire electronically. The panel was representative of the demographic characteristics (i.e., gender, age) of the Japanese population. 2,222 residents were sampled and 813 responded (i.e., 36.6%).

Table 7 provides a comparison between the Japanese survey panel and the national average. The Japanese survey panel had a larger portion of 20–40 year olds and a smaller portion of over 60 year olds compared to the national average. One key reason for this is that Japanese internet penetration in older people is still low (65–59 years old: 37.6%, 70–79 years old: 27.7%, over 80 years old: 14.5%).

Table 7: Comparison between Japanese survey panel and national average

	Japanese Survey Panel (N=813)	*National Average*[a]
Proportion female	50%	52%
Proportion Age ≤ 29	17%	15%
30 ~ 39	22%	18%
40 ~ 49	20%	15%
50 ~ 59	20%	19%
≥ 60	21%	33%

[a.] Reference: Statistics Bureau. (2006). 2005 population census. Summary of the results: Chapter 1: Size and geographical distribution of the population. Ministry of Internal Affairs and Communications.

Dutch panel

The Dutch sample was drawn from a large Dutch polling firm's respondent panel using stratified random sampling of the Dutch population over the age of 18. Respondents completed the questionnaire individually online. The distribution of age and gender across the sample was similar to that of the general Dutch population.

Table 8: Comparison between Netherlands survey panel and national average

	Dutch Survey Panel (N=848)	*National Average*[a]
Proportion female	50%	51%
Proportion Age ≤ 29	15%	16%
30 ~ 39	15%	16%
40 ~ 49	20%	19%
50 ~ 59	18%	17%
≥ 60	32%	32%

[a.] Reference: CBS (2010) "Key figures"

Appendix E Selected Qualitative Results

Knowledge of CO_2: Example responses

- *"It is emitted from cars etc. I have no idea about the properties, but it is polluting. It comes from factories, when something's burned. I don't know what it is used for". (Netherlands focus group)*
- *"I cannot provide specifics on all its characteristics but I do know for sure that it is a dangerous gas". (Australian interviewee)*
- *"I think CO_2 destroys ecosystems". (Japanese focus group member)*
- *"It is everywhere in space and earth. Too much CO_2 erodes the ozone layer". (Netherlands focus group)*
- *"It contains oxygen, causes global warming and is a natural gas". (Netherlands focus group)*

Knowledge of climate change: Example responses

- *"I don't know the relationship between CO_2 and global warming, but currently, people say the cause is CO_2". (Japanese interview)*
- *"Natural part of the climate cycle – no need for hysteria". (Australian focus group)*
- *"Warmer winters were said to be a symptom of climate change. Much is said about CO_2 being the cause. But the winter this year was very cold, despite what they predicted. I don't know what to believe anymore. They completely missed the mark". (Netherlands focus group)*

Perceptions of CO_2: Example responses

- *"When I picture CO_2 an explosion comes to mind, yes highly flammable signs over cylinders". (Australian interviewee)*
- *"Toxic gas that can kill people". (Australian focus group)*
- *"I think carbon is good, but at certain levels. The rate at which we are putting this gas into the atmosphere is too high for the natural system to process so we need to look at reducing this amount. But for CO_2 itself, I think it is a much needed part of the natural system" (Australian focus group)*
- *"It is bad for the environment". (Netherlands focus group)*
- *"It raises the image of climate change and exhaust fumes. But it is also an essential part of life, trees and plants process CO_2". (Netherlands focus group)*
- *"CO_2 fouls the earth". (Japanese focus group)*
- *"We need to get ideas how to cut the emissions". (Japanese focus group)*

Knowledge of CCS: Example responses

- *“CO_2 is stored like nuclear waste, in large containers or concrete bunkers under the ground”. (Australian interviewee)*
- *“CO_2 is absorbed by something”. (Japanese interviewee)*

Perceptions of CCS: Example responses

- *“I think CCS implementation itself is a good option”. (Japanese focus group)*
- *“It’s good that something happens, but this is actually hiding the problem”. (Netherlands focus group)*
- *“Seems like a short term solution to a bigger problem. We probably have not spent enough time and effort reducing the CO_2 to begin with. Then we would not have to bury it”. (Australia focus group)*

Opinions on CCS implementation: Example responses

- *“Where are they thinking about burying this stuff? Better not be near communities or my house”. (Australian focus group)*
- *“I’m opposed to CCS if it is implemented near my house”. (Japanese focus group)*
- *“It says it is expected that the CO_2 will stay there, but that means they are not sure! I want them to be certain first”.(Netherlands focus group)*

Effects of providing information: Example responses

- *“But that has been done naturally. Maybe man cannot replicate what nature does”. (Australian focus group)*
- *“I think this info is important as specific numbers of casualties are clearly presented. This shows risks in specific examples which may happen during CCS implementation. This is convincing for me to make determination”. (Japanese focus group)*
- *“This makes us more negative, because this is a natural phenomenon and CCS isn’t”. (Netherlands focus group)*
- *“If there was an accident then at least it won’t burn”. (Australian focus group)*
- *“How can CO_2 kill people and plants and not be toxic? Then it’s toxic isn’t it?” (Netherlands focus group)*

- *“But that has been done naturally. Maybe man cannot replicate what nature does”. (Australian focus group)*
- *“I think this info is important as specific numbers of casualties are clearly presented. This shows risks in specific examples which may happen during CCS implementation. This is convincing for me to make determination”. (Japanese focus group)*
- *“This makes us more negative, because this is a natural phenomenon and CCS isn’t”. (Netherlands focus group)*

- *“I get worried because there is a lot of information about the influences. It needs to be known”. (Japanese focus group)*
- *“Again, this explains the possible drawbacks of CCS”. (Netherlands focus group)*

- *"Water is such a precious thing, especially in Australia. Maybe we should not jeopardize this resource". (Australian focus group)*

Appendix F Selected Quantitative Results and Interpretation

Set A: CO_2 impression

Table 9: Regression analysis on influence of CO_2 knowledge and respondents' demographics on first assessment of CO_2 impressions

	Dependent Variables	CO_2Positive1	CO_2Clean1	CO_2Useful1	CO_2Safe1	CO_2impression1score (Total)
		std. coef	std. coef	std. coef	std. coef	std. coef
Value and beliefs	ConvincedGW	-0.141**	-0.092**	-0.072**	-	-0.122**
	Renewable	-	-0.049*	-	-	-
	FossilFuel	-	-	-0.044*	-0.047*	-0.046*
	Risk	-	-	-	-	-
	DoForGW	-	-	-	-0.059**	-
	MoreTax	-	-	-	-	-
CO_2 property	Lighter	-	-	-	-	-
	Naturally	0.073**	0.061**	0.127**	0.078**	0.111**
	Flammable	-	-	-	-0.042*	-0.041*
	Soluble	-	-	-	-	-
	AirContain	-	-	-	-	-
	EasyBD	0.074**	0.062**	0.072**	0.039*	0.082**
CO_2 understanding	PlantNeed	0.113**	0.092**	0.145**	0.081**	0.142**
	Climate	-0.057**	-	-	-	-
	Ozone	-0.072**	-0.101**	-0.070**	-0.083**	-0.110**
	CO	-0.052*	-0.047*	-0.050*	-0.070**	-0.072**
	Toxic	-0.072**	-0.051*	-	-0.126**	-0.070**
	Soot	-0.100**	-0.187**	-0.095**	-0.124**	-0.168**
CO_2 source	PowerPlant	-0.150**	-0.139**	-0.066**	-0.060**	-0.137**
	Human	-	-	-	0.060**	-
	PlantAbsorb	-	-	-	-	-
	Ocean	0.055**	0.055**	-	0.048*	0.063**
	DifferentSubstance	-	-	-	-	-
CO_2 uses	Cola	0.086**	0.104**	0.063**	0.034	0.097**
	Greenhouse	0.057**	0.038*	0.090**	0.043*	0.077**
	FireExtinguisher	-	-	0.053*	-	-
	Tyre	-	-	-	-	-
	InputInd	-0.084**	-0.086**	-0.043*	-0.092**	-0.099**
CCS awareness	KnowCCS_dmy	-	-	-	-	-
	KnowLittleCCS_dmy	-	-	-	-0.059**	-
	HeardCCS_dmy	-	-	-	-	-
Trustworthy source	NationalGov	-	-	-	-	-
	LocalGov	-	-	-	-	-
	NationalTV	-	-	-	-	-
	NationalPaper	-	-	-	-	-
	LocalPaper	-	-	-	-	-
	Scientist	-	-	0.040*	-	-
	Developer	-	-	-	0.059**	0.039*
	NationalNGO	-0.047*	-	-	-0.070**	-0.064**
	LocalNGO	-	-0.080**	-0.046*	-	-
	Friend	-	-	-	-	-
	Website	-	0.043*	-	-	-
	UNagency	-	-	-	-	-
CO_2 related activity	Activity	-	-	0.050**	-	-
Information gathering topics	Nature	-	-	-	-	-
	Environment	-	-	-	-	-
	Physics	-	0.071**	-	-	-
	News	-0.058**	-0.065**	-	-	-0.042*
	Technology	0.043*	-	-	-	-
	Biology	-	-	-	-	-
	Science	-	-	-	-	-

Demographics	Univ_dmy	-	-	-	-	-
	Female_dmy	-	-	-	-	-
	U20s_dmy	-0.044*	-	-	-0.046*	-0.036*
	a30s_dmy	-	-	-	-	-
	a40s_dmy	-	-	-	-	-
	a50s_dmy	-	-	-	-	-
	O60s_dmy	-	-	-	-	-
	Csea_dmy	-	-	-	-	-
Adjusted R-squared		0.241	0.259	0.179	0.200	0.343

Note) *: significant level below 5%, **: significant level below 1%
(MC): the covariate is excluded from the regression analysis because of high multicollinearity with other covariate (VIF is higher than 10)

The table above shows to what extent the used knowledge items explain the respondent's answer to each of the four perception items. Each column represents one of the perception items. The first one is the negative-positive scale, the second the dirty-clean scale, the third the useless-useful scale, and last column is the dangerous-safe scale. The explanatory values of the measured knowledge items vary between adj. $R^2 = .18$ and adj. $R^2 = .26$, which are all fairly low. This means for example that 24% of the variance of answers people give on the negative-positive scale are explained by the knowledge items in the survey. The other 76% is explained by factors not measured in this part of the survey. For a summary of results, see report body text.

Table 10: T-tests for changes between the first assessment and the second assessment on CO2 perception

No	Condition (provided information)	N	Statistics	Positive (5)-Negative (1)	Clean (5)-Dirty (1)	Useful (5)-Useless (1)	Dangerous (1)-Safe (5)
1	**CO_2 characteristics**	287	Mean (difference)	0.185	0.213	0.150	-0.056
			Std error	0.057	0.054	0.058	0.054
			t	3.213	3.947	2.563	-1.029
			P-value	0.001	0.000	0.011	0.305
2	**CO_2 impacts & natural phenomena**	272	Mean (difference)	-0.029	0.018	-0.250	-0.460
			Std error	0.060	0.063	0.058	0.065
			t	-0.492	0.293	-4.301	-7.024
			P-value	0.623	0.770	0.000	0.000
3	**CO_2 behaviour in CCS**	269	Mean (difference)	0.026	0.074	-0.138	-0.216
			Std error	0.059	0.057	0.059	0.062
			t	0.443	1.309	-2.318	-3.488
			P-value	0.658	0.192	0.021	0.001
4	**CO_2 characteristics +CO_2 impacts & natural phenomena**	272	Mean (difference)	0.085	0.044	-0.037	-0.257
			Std error	0.054	0.054	0.060	0.064
			t	1.580	0.816	-0.615	-4.021
			P-value	0.115	0.415	0.539	0.000
5	**CO_2 characteristics +CO_2 behaviour in CCS**	286	Mean (difference)	0.154	0.143	0.045	-0.070
			Std error	0.057	0.055	0.058	0.061
			t	2.677	2.614	0.778	-1.140
			P-value	0.008	0.009	0.437	0.255
6	**CO_2 impacts & natural phenomena + CO_2 behaviour in CCS**	277	Mean (difference)	0.040	0.054	-0.152	-0.347
			Std error	0.064	0.059	0.059	0.059
			t	0.617	0.921	-2.572	-5.846
			P-value	0.538	0.358	0.011	0.000
7	**CO2 characteristics + CO_2 impacts & natural phenomena + CO_2 behaviour in CCS**	266	Mean (difference)	0.143	0.158	0.064	-0.357
			Std error	0.063	0.065	0.067	0.066
			t	2.256	2.439	0.952	-5.429
			P-value	0.025	0.015	0.342	0.000
8	**Control**	541	Mean (difference)	0.000	0.092	-0.262	-0.144
			Std error	0.043	0.040	0.044	0.041
			t	0.000	2.316	-5.959	-3.511
			P-value	1.000	0.021	0.000	0.000
9	**All condition**	2470	Mean (difference)	0.185	0.213	0.150	-0.056
			Std error	0.057	0.054	0.058	0.054
			t	3.213	3.947	2.563	-1.029
			P-value	0.001	0.000	0.011	0.305

Positive effect P<0.01

Negative effect P<0.01

Positive effect P<0.05

Positive effect P<0.05

The table above shows the comparison of the seven conditions in which respondents receive new information about CO_2 with the two control conditions in which the general information about CCS is repeated.

Respondents who received information about characteristics and effects of CO_2 (condition A) became on average significantly more positive about CO_2 (difference between means 0.19, $p<0.01$). This effects was still significant when this information was given in combination with information about CO_2 behaviour in CCS (condition AC), but the mean difference was slightly lower (0.15, $p<0.01$).

In both of these conditions, A and AC, respondents afterwards also perceived CO_2 to be significantly cleaner. In condition A the difference between means was 0.21 ($p <0.01$), while in condition AC the mean difference was 0.14 ($p<0.01$).

Respondents perceived CO_2 as less useful after reading information about natural phenomena involving CO_2 (difference between means -0.25, $p<0.01$). This is also the case after reading information about CO_2 behaviour in CCS (difference between means -0.14, $p<0.05$) and after reading a combination of this information (difference between means -0.15, $p<0.05$). After the provision of information about CO_2 characteristics respondents perceived CO_2 as slightly more useful (difference between means -0.15, $p<0.05$).

Information in all conditions made respondents perceive CO_2 as significantly more dangerous, except the information about CO_2 characteristics and CO_2 behaviour in CCS. The strongest change occurred after respondents read the information about the natural phenomena involving CO_2 (difference between means -0.46, $p<0.01$). Despite this increase in perceived danger of CO_2 there was no significant change on how positive or negative respondents perceive CO_2 to be after reading this information.

In the condition where respondents read all parts of the information they became slightly, though significantly, more positive about CO_2 (difference between means 0.14, $p<0.05$), and they perceive it as slightly, though significantly, more clean (difference between means 0.16, $p<0.05$). However, the most significant change is they perceived it as significantly more dangerous (difference between means -0.36, $p<0.01$).

Table 11: ANOVA (three factors) for influences of information package in changes between the first assessment and the second assessment on CO_2 perception

Factor (provided information)	Statistics	Positive (5)-Negative (1)	Clean (5)-Dirty (1)	Useful (5)-Useless (1)	Dangerous (1)-Safe (5)
CO_2 characteristics	Type III sum of squares	10.286	3.723	38.458	6.647
	F	10.564	4.079	38.244	6.527
	P-value	0.001	0.044	0.000	0.011
CO_2 impacts & natural phenomena	Type III sum of squares	0.590	2.258	1.057	32.070
	F	0.606	2.474	1.051	31.490
	P-value	0.436	0.116	0.305	0.000
CO_2 behaviour in CCS	Type III sum of squares	0.551	0.142	1.769	0.192
	F	0.566	0.156	1.759	0.189
	P-value	0.452	0.693	0.185	0.664
CO_2 characteristics x CO_2 impacts & natural phenomena (interaction term)	Type III sum of squares	0.334	0.130	1.017	0.066
	F	0.343	0.143	1.011	0.065
	P-value	0.558	0.705	0.315	0.799
CO_2 characteristics x +CO_2 behaviour in CCS (interaction term)	Type III sum of squares	0.168	0.027	1.890	0.887
	F	0.172	0.029	1.879	0.871
	P-value	0.678	0.865	0.171	0.351
CO_2 impacts &natural phenomena x + CO_2 behaviour in CCS (interaction term)	Type III sum of squares	0.641	2.056	1.168	0.358
	F	0.658	2.253	1.162	0.352
	P-value	0.417	0.133	0.281	0.553
CO_2 characteristics x CO_2 impacts & natural phenomena x CO_2 behaviour in CCS (interaction term)	Type III sum of squares	0.078	0.611	1.967	2.674
	F	0.080	0.670	1.956	2.626
	P-value	0.778	0.413	0.162	0.105
	Type III sum of squares Corrected Total	2410.573	2255.5	2529.321	2549.942
	df	2469	2469	2469	2469
	Adjusted R Squared	0.003	0.001	0.018	0.014

Positive effect P<0.01
Negative effect P<0.01
Positive effect P<0.05
Positive effect P<0.05
Whether positive or negative is judged by sign of mean of change in each variable

Set B: CCS impression

Table 12: Regression analysis on understanding score of CCS

	Dependent:	KS_CCS	Question statement
Category	**Variables**	**std. coef**	
Value and beliefs	ConvincedGW		I am convinced that climate change (global warming) is happening.
	Renewable		We should promote the use of renewable energy as soon as possible.
	FossilFuel		I am worried about fossil fuels running out.
	Risk		It is important for our society to accept some risks related to new technologies.
	DoForGW		Something should be done about climate change (global warming) now.
	MoreTax	-0.052**	I refuse to pay more tax to address climate change (global warming).
CO_2 property	Lighter		CO_2 is lighter than air.
	Naturally		CO_2 occurs naturally.
	Flammable	-0.109**	CO_2 is flammable.
	Soluble		CO_2 is soluble in water.
	AirContain		The air around us contains CO_2.
	EasyBD	-0.035*	It is easy to break down CO_2.
CO_2 understanding	PlantNeed		Plants and trees need CO_2 to grow.
	Climate	0.049*	CO_2 influences the climate.
	Ozone	-0.085**	CO_2 harms the ozone layer.
	CO	-0.100**	CO_2 has the same effect on humans as CO (carbon monoxide).
	Toxic	0.047*	CO_2 in high concentrations is toxic for the human body.
	Soot	-0.113**	CO_2 affects human health in the same way as air pollution substances such as soot.
CO_2 source	PowerPlant	0.118**	CO_2 is released during electricity production from power plants using natural gas or coal.
	Human		The human body creates CO_2.
	PlantAbsorb	0.050**	CO_2 is absorbed by plants and trees.
	Ocean		CO_2 is absorbed by oceans.
	DifferentSubstance	-0.093**	Naturally occurring CO_2 has a different chemical structure to industrially occurring CO_2.
CO_2 uses	Cola		CO_2 is used to make drinks fizzy e.g. cola and soda.
	Greenhouse		Extra CO_2 is put into the air in some greenhouses to help plants grow.
	FireExtinguisher	0.052**	CO_2 is used in some fire extinguishers.
	Tyre	-0.048**	CO_2 is used to make tyres.

<table>
<tr><td></td><td>InputInd</td><td></td><td>CO_2 emissions from industry are much higher than CO_2 inputs into industry.</td></tr>
<tr><td rowspan="7">Provided InfoA</td><td>InfoA</td><td></td><td></td></tr>
<tr><td>InfoChemistry</td><td></td><td>Carbon dioxide (CO_2) consists of one carbon atom and two oxygen atoms bound together. It is mainly produced by burning carbon-containing fuels.</td></tr>
<tr><td>InfoProperty</td><td>0.079**</td><td>Properties:
•Colourless
•Odourless
•Heavier than air, therefore accumulates in low lying areas
•Non-flammable
•Non-explosive at normal pressure
•Water-soluble</td></tr>
<tr><td>InfoGHeffect</td><td></td><td>Causes 'greenhouse effect' in atmosphere. Greenhouse gases in our atmosphere make sure the sun's warmth on earth does not immediately escape out to space. This 'greenhouse effect' provides a habitable climate for plants, animals and humans.</td></tr>
<tr><td>InfoToxicity</td><td></td><td>The toxicity of CO_2 depends on its concentration in the atmosphere. Please read the following table which lists indicative physical effects of increasing CO_2 concentrations.
<table>
<tr><td>Concentration of CO_2 (%)</td><td>Time of exposure to onset (minutes)</td><td>Symptoms</td><td>Example of concentration</td></tr>
<tr><td>0.04%</td><td>Prolonged</td><td>None</td><td>Atmospheric concentration</td></tr>
<tr><td>0.1%</td><td>Prolonged</td><td>None</td><td>Concentration in some hot springs</td></tr>
<tr><td>1%</td><td>Prolonged</td><td>Drowsiness</td><td>Concentration in a closed room full of people</td></tr>
<tr><td>2-6%</td><td>5-30</td><td>Heavier or faster breathing
Headache, dizziness, chills and decrease in sensation</td><td>Breath from humans (100 times atmospheric concentration)</td></tr>
<tr><td>6-10%</td><td>5-60</td><td>Dim vision, tremors and loss of consciousness (risk of death)</td><td></td></tr>
</table></td></tr>
<tr><td>InfoPlace</td><td></td><td>Places where CO_2 exists
•Atmosphere
•Breath from humans
•Forests
•Oceans
•Underground in oil and gas fields and magma chambers from volcanoes</td></tr>
<tr><td>InfoUse</td><td></td><td>Uses of CO_2
•CO_2 is used to make drinks fizzy e.g. cola and soda</td></tr>
</table>

			•Extra CO_2 is put in the air in greenhouses to help plants grow •CO_2 is used in some fire extinguishers
Provided InfoB	InfoB		
	InfoNyos		Lake Nyos is a crater lake in the Northwest Region of Cameroon, containing large amounts of CO_2 from volcanic activity. In 1986 a large cloud of CO_2 was emitted suddenly and became trapped in the valley, suffocating 1,700 people and 3,500 livestock in nearby villages.
	InfoHotSpring		At some hot springs such as Nagayu in Japan and Bad Nauheim in Germany, people experience health benefits such as good blood circulation through bathing in water with high CO_2 concentrations (about 1%).
	InfoPaintfactory		In Moenchengladbach, Germany, 107 people were injured (and 13 of those were treated in hospital) when a CO_2 fire extinguisher system of a paint factory malfunctioned and CO_2 was released. The nearby area was sealed off for a time and residents were ordered to shut their windows and go to higher floors.
	InfoDome		For millions of years, CO_2 has been securely sealed underground in natural underground CO_2 reservoirs. For example, in the USA, CO_2 fields called the Jackson, McElmo, and St. Johns Domes were formed millions of years ago, and together hold 2.4 billion tons of CO_2.
	InfoMtMammoth		In Mammoth Mountain, USA, a large volume of CO_2 seeping from volcanic activity underground has been killing nearby trees.
Provided InfoC	InfoC		
	InfoCapture	0.194**	In industry the capture and compression of CO_2 is common practice. The risks associated with capturing CO_2 from the production process are well known and managed.
	InfoTransport		The CO_2 can be transported in a gas or liquid form using pipelines across large distances. Leaks in pipelines can occur. There is a small chance the leaked CO_2 will accumulate near the leakage point. The USA has a CO_2 pipeline system over 3000 km long which has been in use for more than 20 years. There have been no accidents involving injuries or death.
	InfoCauseEarthquake		The injection of liquid-like CO_2 underground can cause micro earthquakes similar to those caused by natural gas extraction.
	InfoLiquidLike		The CO_2 will enter the storage in a liquid-like form and will not return to a gaseous form as long as it is exposed to typical pressure and temperature found deep underground. Here it will spread out through tiny holes in the rock formation.
	InfoUnderground		Underground, liquid-like CO_2 may affect microbial populations which are important for ecosystem stability, affect nutrient supply, acidify ground water and affect the movement of metals and/or other contaminants.
	InfoLeakSoil		If CO_2 leaks from the storage or injection point into the surrounding soil, there is a small chance it might acidify topsoil and/or impact groundwater and possibly drinking water.
	InfoLeakCracks	-0.114*	If liquid-like CO_2 is stored appropriately, there is a very small chance that small quantities of it would leak through poorly sealed wells, tears and cracks in the caprock layer of the underground storage.
Provided InfoD	InfoCO_2andCC		Carbon dioxide, or CO_2, is one of the green house gases. Concentrations of CO_2 in the air are increased, which is said to be one of the main causes of climate change. Many countries, Australia included, consider it very important to reduce CO_2 emissions. One way to reduce CO_2 emissions is CO_2 capture and storage.
	InfoWhatCCS	0.073**	There are three main steps to successful CO_2 capture and storage. 1) The first step is to capture and separate the CO_2 from other gases, either before or after the fuel, such as coal or natural gas, is burned. 2) The second step is to transport the captured CO_2 to a

			storage location. 3) The final step is storage. The aim is to store the CO_2 underground, virtually permanently. Storage involves injecting liquid-like CO_2 into rock about 1,000 m below the Earth's surface. Here it will not return to a gaseous form while exposed to typical pressure and temperature found at this depth underground. A large amount of stored CO_2 could be trapped underground. Depleted oil and gas reservoirs provide one possibility for long-term storage and another is in geological formations called saline aquifers (i.e. rock formations filled with saline water).
	InfoExtraEnergy		CO_2 capture and storage technology can either be designed into new power plants or fitted onto existing older power plants. New power plants with CO_2 capture and storage technology can reduce CO_2 emissions by approximately 80-90% but they use about 25% extra energy and require additional equipment compared to older conventional power stations.
CCS Consequence (order effects)			
Trustworthy source	NationalGov		National government agencies/organisations
	LocalGov	0.064**	Local/regional government agencies/organisations
	NationalTV		National television programs that I watch
	NationalPaper	0.054*	National newspapers that I read
	LocalPaper		Local newspapers and television that I read/watch
	Scientist	0.073**	Scientists/researchers
	Developer		Project developers, energy companies etc
	NationalNGO	-0.075**	National and/or international non-government organisations (NGOs) such as Greenpeace or WWF
	LocalNGO	-0.054*	Local NGOs and/or community groups, residents' associations etc.
	Friend	-0.059**	Friends, neighbours, family
	Website	-0.065**	Interactive websites (e.g. blogs, wikis etc.)
	UNagency	0.049*	United Nations organisations such as the Intergovernmental Panel on Climate Change (IPCC)
CO_2 related activity	Activity		Do you have any professional or recreational activities which relate to CO_2?
Information gathering topics	Nature		Nature
	Environment		Environment
	Physics	0.043*	Physics
	News	0.036*	News
	Technology		Technology
	Biology		Biology
	Science	0.061**	Science
Demographics	Univ_dmy		
	Female_dmy	-0.045*	
	U20s_dmy		
	a30s_dmy		
	a40s_dmy		

	a50s_dmy		
	O60s_dmy		
	Csea_dmy		
Adjusted R-squared		0.321	

Note) *: significant level below 5% **: significant level below 1%
(MC): the covariate is excluded from the regression analysis because of high multicollinearity with other covariate (VIF is higher than 10)

[MC]: InfoA, InfoC, InfoCauseEarthquake, InfoLiquidLike, InfoLeakSoil

[-]:ConvincedGW, Renewable, FossilFuel, Risk, DoForGW, Lighter, Naturally, Soluble, AirContain, PlantNeed, Human, Ocean, Cola, Greenhouse, InputInd, InfoChemistry, InfoGHeffect, InfoToxicity, InfoPlace, InfoUse, InfoB, InfoNyos, InfoHotSpring, InfoPaintfactory, InfoDome, InfoMtMammoth, InfoTransport, InfoUnderground, InfoCO_2andCC, InfoExtraEnergy, CCS Consequence (order effects), NationalGov, NationalTV, LocalPaper, Developer, Activity, Nature, Environment, Technology, Biology, Univ_dmy, U20s_dmy, a30s_dmy, a40s_dmy, a50s_dmy, O60s_dmy, Csea_dmy

Table 13: Regression analysis on influence of CO_2 knowledge, CO_2 impressions and respondents' demographics on first assessment of CCS impressions

	Dependent: Variables	CCSPositive	CCSClean	CCSUseful	CCSSafe	CCSMature	CCSimpression 1score(Total)
		std. coef	std. coef	std. coef	std. coef	std. coef	std. coef
Value and beliefs	ConvincedGW	0.046*	-	-	-	-	-
	Renewable	-	-	-	-	-0.054**	-
	FossilFuel	-	0.057**	-	-	-	0.048*
	Risk	0.089**	0.073**	0.082**	0.071**	-	0.079**
	DoForGW	-	-	-	-	-	-
	MoreTax	-	-	-0.061**	-	-	-
CO_2 property	Lighter	-	-	-	-	-	-
	Naturally	-	-	-	-	-	-
	Flammable	-	-	-	-	-	-
	Soluble	-	-	-	-	-	-
	AirContain	-	-	-	-	-0.055**	-
	EasyBD	-	-	-	-	0.045*	-
CO_2 understanding	PlantNeed	-	-	-	-	-	-
	Climate	0.041	-	0.089**	-	-	0.046*
	Ozone	0.046*	-	-	-	-	-
	CO	-	-0.046*	-	-	-	-
	Toxic	-	-	-	-	-	-
	Soot	-	-	-	-0.054**	0.081**	-
CO_2 source	PowerPlant	-	0.055*	0.080**	-	-0.071**	-
	Human	-	-	-0.063**	-	-0.113**	-0.065**
	PlantAbsorb	-	0.059**	0.054*	-	0.045*	0.057*
	Ocean	-	-	-	-	-	-
	DifferentSubstance	-	-	-	-	-	-
CO_2 uses	Cola	-	-	-	-	-	-
	Greenhouse	0.044*	-	-	-	-	-
	FireExtinguisher	-	-	-	-	-	-
	Tyre	-	-	-	-	-	-
	InputInd	-	-	-	-	-	-
CO_2 impress	CO_2Positive1	-	-	-0.089**	-	0.058**	-

ion	CO_2Clean1	-	0.048*	-	-	-	-
	CO_2Useful1	-	-	0.122**	-	-	0.040*
	CO_2Dangerous1	-	-	-	0.121**	-	-
CCS awareness	KnowCCS_dmy	-	-	-0.038*	-	-	-
	KnowLittleCCS_dmy	-	-	-	0.040*	-	-
	HeardCCS_dmy	-	-	-	-	0.041*	-
Trustworthy source	NationalGov	0.081**	-	-	0.083**	0.116**	0.112**
	LocalGov	-	-	-	-	-	-
	NationalTV	-	-	0.073**	-	-	-
	NationalPaper	-	0.054*	-	-	-	-
	LocalPaper	-	-	-	-	-	-
	Scientist	0.049*	0.085**	-	-	-	0.051*
	Developer	0.108**	0.101**	0.089**	0.138**	-	0.135**
	NationalNGO	-	-0.061**	-	-	-	-
	LocalNGO	-	-	-0.050*	-	-	-0.060**
	Friend	-0.057**	-0.067**	-0.050*	-	-	-
	Website	-	-	-	-	0.059**	-
	UNagency	0.097**	0.077**	0.153**	0.049*	-	0.082**
CO_2 related activity	Activity	-	0.042*	-	-	-0.095**	-
Information gathering topics	Nature	-	-	-	-	-	-
	Environment	-	-	-	-	-	-
	Physics	-	-	-	-	-	-
	News	-	-	-	-	-	-
	Technology	-	-	-	-	-	-
	Biology	-	-	-	-	-	-
	Science	-	-0.072**	-	-	-	-
Demographics	Univ_dmy	-	0.073**	-	-	-0.068**	-
	Female_dmy	-0.063**	-0.065**	-	-0.083**	-	-0.064**
	U20s_dmy	-	-	-	-	-	-
	a30s_dmy	-	-	-	-	-	-
	a40s_dmy	-	-	-	-	-	-

	a50s_dmy	0.052**	0.062**	-	0.070**	-	0.063**
	O60s_dmy	0.090**	0.088**	-	0.118**	-	0.098**
	Csea_dmy	-	-	-	-	-	-
Adjusted R-squared		0.108	**0.095**	**0.127**	0.085	0.105	0.114

Note) *: significant level below 5%, **: significant level below 1%
(MC): the covariate is excluded from the regression analysis because of high multicollinearity with other covariate (VIF is higher than 10)

For this table, the explanatory scores (adjusted R-squares) were very low (0.095 – 0.127), partially because most of respondents stated impressions instantly when they faced the questions with very simple explanation about CCS. In addition that is partially because covariates directly relevant to CCS were not introduced to the regression because there is not CCS questions before the CCS impression questionnaire.

A person's acceptance of risks related to new technologies (beta 0.079, p < 0.01) had a positive influence on impressions of CCS, including perceiving CCS overall as a "positive" technology (beta 0.09, p.0.01), "clean" (0.09, p < 0.01), "useful" (beta 0.08, p .< 0.01), and "safe" (beta 0.07, p < 0.01). Understanding that CO_2 influences the climate has an effect on respondents perceiving CCS as "useful" (beta 0.09, p<0.01). Believing that CO_2 affects human health in the same way as air pollution substances such as soot (beta 0.08, p < 0.01), influenced the respondents' perceptions about CCS's maturity as a technology. Knowledge that CO_2 emissions result from power plants influences some impressions of CCS positively, such as "usefulness" (beta 0.8, p < 0.01) and perceived maturity of the technology (beta -0.07, p<0.01). Understanding that the human body produces CO_2 has a negative influence on overall CCS perceptions (beta -0.07, p < 0.01). It specifically influences "usefulness" (beta 0.6, p < 0.01) and perceived maturity of the technology (beta -0.11, p < 0.01).

The variable "CCSimpression1TOTAL" was calculated by summing up each respondent' scores of the four CCS impression measures. According to the results of the regression analysis, the total CCS impression score is positively influenced by respondents' perceptions of the trustworthiness of the source of information i.e. developers (beta 0.14, p<0.01), national government (beta 0.11, p<0.01), or UN agency (beta 0.08, p<0.01). Respondents in the 60 or older age group (beta 0.10, p<0.01), or in their 50s (beta 0.06, p<0.01) had more positive impressions of CCS than respondents in their 40s or younger. Women's impressions on CCS were more negative than men's (beta -0.06, p<0.01).

Table 14: ANOVA (three factors) for influences of information in changes between the first assessment and the second assessment on CCS perception

Factors (provided information)	Statistics	Positive (5)-Negative (1)	Clean (5)-Dirty (1)	Useful (5)-Useless (1)	Dangerous (1)-Safe (5)	Matrure(5)-Developing(1)
CO_2 characteristics	Type III sum of squares	0.571	0.556	2.354	2.354	6.033
	F	0.710	0.747	3.285	2.643	7.674
	P-value	0.400	0.387	0.070	0.104	0.006
CO_2 natural phenomena	Type III sum of squares	12.273	2.174	0.668	13.262	1.951
	F	15.245	2.923	0.932	14.892	2.481
	P-value	0.000	0.087	0.335	0.000	0.115
CO_2 behaviour in CCS	Type III sum of squares	4.774	4.623	1.289	1.124	10.837
	F	5.929	6.215	1.798	1.262	13.783
	P-value	0.015	0.013	0.180	0.261	0.000
CO_2 characteristics	Type III sum of squares	3.894	1.715	1.905	0.006	0.035
x CO_2 natural phenomena	F	4.837	2.306	2.658	0.007	0.045
(interaction term)	P-value	0.028	0.129	0.103	0.935	0.833
CO_2 characteristics	Type III sum of squares	0.015	3.958	0.958	0.080	0.501
x CO_2 behaviour in CCS	F	0.019	5.322	1.337	0.090	0.637
(interaction term)	P-value	0.891	0.021	0.248	0.764	0.425
CO_2 natural phenomena	Type III sum of squares	2.847	4.203	0.453	0.662	0.045
x CO_2 behaviour in CCS	F	3.536	5.650	0.632	0.743	0.057
(interaction term)	P-value	0.060	0.018	0.427	0.389	0.811
CO_2 characteristics	Type III sum of squares	0.191	0.277	0.026	0.144	1.354
x CO_2 natural phenomena	F	0.237	0.373	0.036	0.162	1.722
x CO_2 behaviour in CCS (interaction term)	P-value	0.626	0.542	0.850	0.688	0.190
Control	Type III sum of squares	20.903	9.438	9.693	2.263	0.478
+ Consequence	F	25.965	12.689	13.524	2.541	0.608
(order effect)	P-value	0.000	0.000	0.000	0.111	0.436
	Type III sum of squares Corrected Total	2017.804	1854.551	1784.543	2209.936	1960.632
	df	2469	2469.	2469.	2469	2469
	Adjusted R-squared	0.015	0.010	0.008	0.005	0.010

Note) Positive effect P<0.01

Positive effect P<0.05

Negative effect P<0.01

Negative effect P<0.05

Whether positive or negative is judged by sign of mean of change in each variable

Table 15: Regression analysis on influence of provided information on magnitude of change of CCS impressions

	Dependent:	CCSPositiveDF	CCSCleanDF	CCSUsefulDF	CCSSafeDF	CCSMatureDF
Category	**Variables**	**std. coef**	**std. coef**	**std. coef**	**std. coef**	**std. coef**
Provided InfoA	InfoA	-	-	-	0.213**	-
	InfoChemistry	-	-	-0.127*	0.180-**	-
	InfoProperty	-	-	-	-	-
	InfoGHeffect	-	-	-	-	-
	InfoToxicity	-	-	-	-	0.064**
	InfoPlace	-	-	-	-	-
	InfoUse	-	-	0.162**	-	-
Provided InfoB	InfoB	-	-	0.210**	-	-
	InfoNyos	-	-	-	-	-
	InfoHotSpring	-	-	-	-	-
	InfoPaintfactory	-	-	-0.245**	-	-
	InfoDome	-	-	-	-	-
	InfoMtMammoth	-0.092**	-0.050*	-	0.081-**	-
Provided InfoC	InfoC	-	-	-	-	-
	InfoCapture	-	-	-	-	0.089**
	InfoTransport	0.151*	-	-	-	*(MC)*
	InfoCauseEarthquake	-0.204**	-	-	-	-
	InfoLiquidLike	*(MC)*	-	-	-	-
	InfoUnderground	-	-	-	-	-
	InfoLeakSoil	-	-	-	-	-
	InfoLeakCracks	-	-0.057**	-	-	-
Provided InfoD	InfoCO_2andCC	-	-	-	-	-
	InfoWhatCCS	-	-	-	-	-
	InfoExtraEnergy	-	-	-	-	-
CCS Consequence (order effects)		-0.119**	-0.090**	-0.081**	-	-
Adjusted R-squared		0.019	0.008	0.016	0.011	0.012

Note) *: significant level below 5%, **: significant level below 1%
(MC): the covariate is excluded from the regression analysis because of high multicollinearity with other covariate (VIF is higher than 10)

Table 16: Regression analysis on influence of knowledge items, provided information and misperception of CCS on CCS overall impressions

	Dependent:	CCSPositive2	CCSClean2	CCSUseful2	CCSSafe2	CCSMature2	CCSimpression2score(Total)
Category	**Variables**	**std. coef**	**std. coef**	**std. coef**	**std. coef**	**std. coef**	**std. coef**
Value and beliefs	ConvincedGW	-	-	-	-	-	-
	Renewable	-	-	-	-	-	-
	FossilFuel	-	0.052**	-	-	-	0.038*
	Risk	-	-	-	-	-	-
	DoForGW	-	-	-	-	-	-
	MoreTax	-	-	-	-	-	-
CO_2 property	Lighter	-	-	-	-	-	-
	Naturally	-	-	-	-	-	-
	Flammable	-	-	-	-	-	-
	Soluble	-	-	-	-	-0.046*	-
	AirContain	-	-	-	-	-	-
	EasyBD	-	-	-	-	0.052**	-
CO_2 understanding	PlantNeed	-0.041*	-	-	-	-	-0.030*
	Climate	-	-	0.048**	-	-	-
	Ozone	-	-	-	-	-	-
	CO	-	-	-	-	-	-
	Toxic	0.046**	0.037*	0.054**	-	-	-
	Soot	-	-	-	-	0.072**	0.041*
CO_2 source	PowerPlant	-	-	-	-	-0.074**	-
	Human	-	-	-	-	-0.040	-
	PlantAbsorb	-	-	-	-	-	-
	Ocean	-	-	-	-	-	-
	DifferentSubstance	0.035*	-	-	-	0.053*	0.062**
CO_2 uses	Cola	-	-	-	-	-0.052**	-
	Greenhouse	0.034*	-	-	-	-	-
	FireExtinguisher	-	0.048**	-	-	-	-
	Tyre	-	-	-	-	-	-
	InputInd	-	-	-	0.043*	-	-
CCS awareness	KnowCCS_dmy	-	-	-0.032*	-	-	-
	KnowLittleCCS_dmy	-	-	-0.044**	-	-0.058**	-
	HeardCCS_dmy	-	-	-	-	-	-
Provided InfoA	InfoA	*(MC)*	-	-	*(MC)*	-	*(MC)*
	InfoChemistry	-	-	*(MC)*	-	-	-
	InfoProperty	0.052**	-	0.037*	-	-	0.041*
	InfoGHeffect	-	-	-	-	-	-
	InfoToxicity	-	-	-	0.040*	-	-
	InfoPlace	-	-	-	-	-	-
	InfoUse	-	-	-	-	-	-
Provided InfoB	InfoB	-	-	-	-	-	-
	InfoNyos	-	-	-	-	-	-
	InfoHotSpring	-	-	-	-	-	-
	InfoPaintfactory	-	-	-	-	-	-

	InfoDome	-	-	-	-	-	-
	InfoMtMammoth	-	-	-	-	-	-
Provided InfoC	InfoC	*(MC)*	*(MC)*	-	*(MC)*	-	-
	InfoCapture	*(MC)*	*(MC)*	-	*(MC)*	0.044*	*(MC)*
	InfoTransport	*(MC)*	*(MC)*	-	*(MC)*	-	*(MC)*
	InfoCauseEarthquake	-0.050**	-0.055**	-	-	-	-0.034*
	InfoLiquidLike	*(MC)*	-	-	*(MC)*	-	*(MC)*
	InfoUnderground	*(MC)*	-	-	-	-	-
	InfoLeakSoil	*(MC)*	*(MC)*	-	-0.067**	-	*(MC)*
	InfoLeakCracks	*(MC)*	-	-	-	-	-
Provided InfoD	InfoCO_2andCC	0.120**	-	*(MC)*	-	-	-
	InfoWhatCCS	-	-	*(MC)*	-	-	*(MC)*
	InfoExtraEnergy	-	-	0.141**	-	-	0.104**
CCS Consequence (order effects)		-0.104**	-	-0.096**	-	-	-0.090**
CO_2 impression2	CO_2Positive2	0.160**	-	-	-	0.052*	0.051*
	CO_2Clean2	-	0.190**	-	-	0.055*	0.083**
	CO_2Useful2	-	0.051*	0.194**	-0.121**	0.053*	0.060**
	CO_2Dangerous2	-0.059**	-0.058**	-0.095**	0.328**	-	-
CCS consequence likelihood	MoveAtmosphere	-0.090**	-0.061**	-0.088**	-0.066**	-0.082**	-0.105**
	Soil	-0.056**	-0.074**	-	-	-	-0.049*
	LeakOn	-	-	-	-0.075**	-	-
	LeakOff	-	-	-	-	-	-
	FlowIntoSea	-	-	-	-	0.078**	-
	EarthquakeLeak	-	-	-	-0.051*	-0.071**	-
CCS consequence misperception	ChemicalReact	-	-0.076**	-	-	-	-
	Caprock	-	-	-	-0.045*	-	-
	Fire	-	-	-	-	-	-
	Ecosystem	-	-	-	-	-0.052*	-0.042*
	Vacant	-	-	-	-	-	-
	Radiation	-	-	-	0.053**	-	-
	Solid	-0.052**	-	-0.079**	-	-	-0.040*
CCS perception and opinion	MeasureMonitor	0.046**	0.051**	0.061**	0.081**	0.064**	0.089**
	BreakDown	-	-	-	-0.056**	-	-0.033
	ManyRisk	-0.251**	-0.256**	-0.237**	-0.143**	-0.091**	-0.256**
	Gurantee	-	0.091**	0.043*	-	-	-
	MitigateCC	0.264**	0.149**	0.266**	0.052**	0.046*	0.213**
	KnowEnough	0.090**	0.077**	0.058**	0.072**	0.137**	0.125**
	WhatHappen	-	-	-	-0.058**	-0.046*	-
Trustworthy source	NationalGov	-	-	0.055**	-	-	0.055**
	LocalGov	-	-	-	-	-	-
	NationalTV	-	-	-	-	-	-
	NationalPaper	-	-	-	-	-	-
	LocalPaper	-	-	-	-	-	-
	Scientist	-	0.063**	-	-	-	-
	Developer	0.057**	0.040*	-	0.067**	-	0.050**

	NationalNGO	0.044*	-	-	0.041*	-	-
	LocalNGO	-0.054**	-	-	-	-	-
	Friend	-	-0.041*	-0.052**	-	-	-
	Website	-	-	-	-	0.048*	-
	UNagency	0.048*	-	0.061**	-	-	-
CO_2 related activity	Activity	-	-	-	-	-	-
Information gathering topics	Nature	-	-	-	-	-	-
	Environment	-	-	-	-	-	-
	Physics	-	-	-	-	-	-
	News	-	-	-	-	-	-
	Technology	-	-	-	-	-	-
	Biology	-	-	-	-	-	-
	Science	-	-0.049**	-	-	-	-
Demographics	Univ_dmy	-	-	-	-	-0.043*	-
	Female_dmy	-	-	-	-	-	-
	U20s_dmy	-	-	-	-0.060**	-	-
	a30s_dmy	-	-	-	-	-	-
	a40s_dmy	-	-0.033*	-	-	-	-
	a50s_dmy	-	-	-	-	-	-
	O60s_dmy	-	-	-	0.055**	-	0.031*
	Csea_dmy	-	-	-	-	-	-
Country	CountryJP	-	-	-	-	-	-
	CountryNL	-	-0.045*	-	-	0.107**	-
Adjusted R-squared		0.388	0.332	0.364	0.336	0.202	0.452

Note) *: significant level below 5%

**: significant level below 1%

(MC): the covariate is excluded from the regression analysis because of high multicollinearity with other covariate (VIF is higher than 10)

Set C: Opinions on CCS implementation

Table 17: Regression analysis on influence of CO_2 knowledge, CO_2 impressions and respondents' demographics on first assessment of CCS implementation

	Dependent:	ImplementCountry1	ImplementOnshore1	ImplementOffshore1
Category	Variables	std. coef	std. coef	std. coef
Value and beliefs	ConvincedGW	0.071**	-	-
	Renewable	-	-	-0.045*
	FossilFuel	-	-	-
	Risk	0.081**	0.103**	0.103**
	DoForGW	-	-	-
	MoreTax	-0.063**	-0.107**	-0.101**
CO_2 property	Lighter	-	-	-
	Naturally	-	-	-
	Flammable	-	-	-
	Soluble	-	-	-
	AirContain	-	-0.052**	-
	EasyBD	-	-	-
CO_2 understanding	PlantNeed	-	-	-
	Climate	0.070**	-	0.085**
	Ozone	-	-	-
	CO	-	-	-
	Toxic	-	-	-
	Soot	-	-	-
CO_2 source	PowerPlant	-	-	-
	Human	-	-	-0.079**
	PlantAbsorb	-	-	-
	Ocean	-	-	-
	DifferentSubstance	-	-	-
CO_2 uses	Cola	0.056**	0.065**	0.052*
	Greenhouse	-	-	0.063**
	FireExtinguisher	-	-	-
	Tyre	-	-	-
	InputInd	-	-	-
CO_2 impression1	CO_2Positive1	-	-	-
	CO_2Clean1	-	0.067**	-
	CO_2Useful1	-	-	-
	CO_2Dangerous1	-	-	-
CCS awareness	KnowCCS_dmy	-	-	-
	KnowLittleCCS_dmy	-	0.064**	0.068**
	HeardCCS_dmy	-	-	-
Trustworthy source	NationalGov	0.087**	0.117**	0.139**
	LocalGov	-	-	-
	NationalTV	-	-	-
	NationalPaper	-	-	-
	LocalPaper	-	-	-
	Scientist	0.050*	-	0.085**
	Developer	0.138**	0.123**	0.052*

	NationalNGO	-	-0.075**	-0.050*
	LocalNGO	-0.054**	-	-0.060**
	Friend	-	-	-
	Website	-	-	0.045*
	UNagency	0.093**	0.102**	0.080**
CO_2 related activity	Activity	-	-	-0.066**
Information gathering topics	Nature	-	-	-
	Environment	-	-	-0.078**
	Physics	-	-	-
	News	-	-0.062**	-
	Technology	-	-	-
	Biology	-	-	-
	Science	-	-	-
Demographics	Univ_dmy	-	-	0.049*
	Female_dmy	-0.094**	-0.118**	-0.078**
	U20s_dmy	-	-	-
	a30s_dmy	-	-	-
	a40s_dmy	-	-	-
	a50s_dmy	-	-	0.054**
	O60s_dmy	0.041*	-	0.078**
	Csea_dmy	-	-	-
Adjusted R-squared		0.137	0.134	0.173

Note) *: significant level below 5%, **: significant level below 1%
(MC): the covariate is excluded from the regression analysis because of high multicollinearity with other covariate (VIF is higher than 10)

Although the adjusted R-squared (0.134 – 0.173) indicates the regressions did not fully explain the factors that influence respondents' opinion formation about CCS implementation, the covariates of value and beliefs category and trustworthy source category did mainly explain the opinions on CCS implementation across the three regressions as found below.

- The largest covariates to explain opinion on CCS in country were "Developer" (trustworthy source) providing a positive effect, "Female dummy" providing a negative effect, UN Agency" (trustworthy source) providing a positive effect, "NationalGov" (national government as a trustworthy source) providing a positive effect and "Risk" (support for the opinion for our society to accept some risks related to new technologies) providing a positive effect.

- The largest covariates to explain opinion on CCS onshore (neighbourhood) were "Developer" providing a positive effect, "Female dummy", "NationalGov" providing a positive effect, "MoreTax" (refusal to pay more tax to address climate change) providing a negative effect, "UN Agency" providing a positive effect, and "Risk" providing a positive effect.

- The largest covariates to explain opinion on CCS offshore (neighbourhood) were "NationalGov" providing a positive effect, "Risk" providing a positive effect, "MoreTax", "Developer" providing a positive effect, "Scientist" providing a positive effect and "UN Agency" providing a positive effect.

- Some covariates were commonly statistically significant across the three regressions. "Risk" has a positive influence (beta 0.08-0.11, $p < 0.01$) and "More tax" had a negative influence (beta -0.06 – -0.1, $p < 0.01$) in the value and beliefs category. A person's tendency to accept technology related risk and support for using tax money to address climate change correlated to support of CCS implementation.

- In the trustworthy category, we also found some variables significantly significant across the three regressions. Trust in “NationalGov” (beta 0.09, 0.10, 0.14; $p < 0.01$), “Developer” (beta 0.14, 0.12, 0.5; $p < 0.01$) and “UN agency” (beta 0.09, 0.10, 0.08; $p < 0.01$) had a positive influence in terms of forming opinions on CCS implementations. In contrast, trust in NGOs provided had a negative influence. “National NGOs” influenced opinions about CCS “onshore” (beta -0.08, $p < 0.01$) and CCS off “shore” (beta -0.05, $p < 0.05$). Trusts in relation to “Local NGOs” influenced opinions on CCS “in your country” (beta -0.05, $p < 0.01$) and on CCS “offshore” (beta -0.06, $p < 0.01$).

- In the understanding of CO_2 category, understanding the influence CO_2 has on the climate had a positive effect on the opinion of CCS “in your country” and CCS “offshore” (beta 0.07 and 0.085, $p < 0.01$). A basic cause-effect understanding of climate change was relevant to attitude on and the role of CO_2 in it is influential for an understanding of CCS. This effect was not significant when it came to implementation of CCS. in a respondent’s neighbourhood.

- As for CCS awareness, “know LittleCCS dmy” indicates those who “have heard about it and know a little about CCS” were more favourable (beta 0.06 and 0.07, $p < 0.01$) towards CCS implementation than those who had less knowledge of or much knowledge of CCS.

- Knowledge of CO_2 use “Cola” had a positive effect on opinions about CCS implementations (beta 0.06 $p < 0.01$, beta 0.07 $p < 0.01$, beta 0.05 $p < 0.05$).

- As for demographic covariates, it was revealed that women were significantly less favourable towards CCS implementation (beta -0.09, -0.12, -0.8, $p < 0.01$). In addition, the age over 60 dummy indicates that this age group were more supportive of CCS “in your country” and CCS “offshore” (statistically significant at 5% level and 1% level respectively).

Table 18: ANOVA (four factors) for influences of information in changes between the first assessment and the second assessment on opinions on CCS implementations

Factors (provided information)	Statistics	Implementation country Favour (5)-Against (1)	Implementation Onshore Favour (5)-Against (1)	Implementation Offshore Favour (5)-Against (1)
CO_2 characteristics	Type III sum of squares	7.773	4.043	4.454
	F	13.537	7.168	7.485
	P-value	0.000	0.007	0.006
CO_2 natural phenomena	Type III sum of squares	3.803	4.278	4.657
	F	6.623	7.584	7.826
	P-value	0.010	0.006	0.005
CO_2 behaviour in CCS	Type III sum of squares	2.447	2.631	1.404
	F	4.261	4.664	2.360
	P-value	0.039	0.031	0.125
CO_2 characteristics	Type III sum of squares	0.058	1.433	0.680
x CO_2 natural phenomena	F	0.101	2.540	1.142
(interaction term)	P-value	0.751	0.111	0.285
CO_2 characteristics	Type III sum of squares	0.252	0.158	0.187
x CO_2 behaviour in CCS	F	0.439	0.280	0.315
(interaction term)	P-value	0.508	0.596	0.575
CO_2 natural phenomena	Type III sum of squares	0.004	0.181	0.144
x CO_2 behaviour in CCS	F	0.007	0.321	0.242
(interaction term)	P-value	0.935	0.571	0.623
CO_2 characteristics	Type III sum of squares	0.328	1.107	0.597
x CO_2 natural phenomena	F	0.571	1.962	1.003
x CO_2 behaviour in CCS (interaction term)	P-value	0.450	0.161	0.317
Control	Type III sum of squares	1.556	1.001	5.084
+ Consequence	F	2.709	1.775	8.544
(order effect)	P-value	0.100	0.183	0.003
	Type III sum of squares Corrected Total	1430.259	1402.128	1481.032
	df	2469	2469	2469.
	Adjusted R-squared	0.009	0.007	0.008

Note) [dark blue] Positive effect P<0.01
[light blue] Positive effect P<0.05
[magenta] Negative effect P<0.01
[pink] Negative effect P<0.05
Whether positive or negative is judged by sign of mean of change in each variable

Table 19: Regression analysis on influence of provided information on magnitude of change of CCS implementation

	Dependent:	ImplementCountyrDF	ImplementOnshoreDF	ImplementOffshoreDF
Category	**Variables**	**std. coef**	**std. coef**	**std. coef**
Provided InfoA	InfoA	0.089**	-	0.071**
	InfoChemistry	-	-	-
	InfoProperty	-	0.060**	-
	InfoGHeffect	-	-	-
	InfoToxicity	-	-	-
	InfoPlace	-	-	-
	InfoUse	-	-	-
Provided InfoB	InfoB	0.233**	-	-
	InfoNyos	-	-	-
	InfoHotSpring	-	0.132**	0.223**
	InfoPaintfactory	-	-	-0.270**
	InfoDome	-	-	-
	InfoMtMammoth	-0.295**	-0.192**	-
Provided InfoC	InfoC	-	-	-
	InfoCapture	-	-	-
	InfoTransport	-	0.147*	-
	InfoCauseEarthquake	-	-	-
	InfoLiquidLike	-	-	-
	InfoUnderground	-	-	-
	InfoLeakSoil	-	-	-
	InfoLeakCracks	-	-0.196**	-
Provided InfoD	InfoCO_2andCC		-	0.066*
	InfoWhatCCS	-	-	-
	InfoExtraEnergy	-	-	-
CCS Consequence (order effects)		-	-	-0.089**
Adjusted R-squared		0.017	0.015	0.019

Note) *: significant level below 5%, **: significant level below 1%
(MC): the covariate is excluded from the regression analysis because of high multicollinearity with other covariate (VIF is higher than 10)

Table 20: Regression analysis on influence of knowledge items, provided information and misperception of CCS on CCS implementation

	Dependent:	ImplementCountry2	ImplementOnshore2	ImplementOffshore2
Category	**Variables**	**std. coef**	**std. coef**	**std. coef**
Value and beliefs	ConvincedGW	-	-	-
	Renewable	-	-	-
	FossilFuel	-	-	-
	Risk	-	0.037 *	0.049 **
	DoForGW	-	-	-
	MoreTax	-0.044 **	-0.056 **	-0.046 **
CO_2 property	Lighter	-	-	-
	Naturally	-	-	-0.038 *
	Flammable	-	-	-
	Soluble	-	-	-
	AirContain	-	-0.038 *	-
	EasyBD	-	0.034 *	-
CO_2 understanding	PlantNeed	-0.046 **	-	-0.039 *
	Climate	0.052 **	-	0.046 **
	Ozone	-	-	-
	CO	-	0.041 *	-
	Toxic	-	-	0.036 *
	Soot	0.057 **	-	-
CO_2 source	PowerPlant	0.042 *	-	0.086 **
	Human	-	-	-
	PlantAbsorb	-	-	-
	Ocean	-	-	-
	DifferentSubstance	-	-	-
CO_2 uses	Cola	-	0.048 **	-
	Greenhouse	0.045 **	-	0.068 **
	FireExtinguisher	-	-	-
	Tyre	-	-	-
	InputInd	-	-	-
CCS awareness	KnowCCS_dmy	-	-	-
	KnowLittleCCS_dmy	-	-	-
	HeardCCS_dmy	-	-	-
Provided InfoA	InfoA	*(MC)*	-	*(MC)*
	InfoChemistry	*(MC)*	-	*(MC)*
	InfoProperty	0.074 **	-	0.046 **
	InfoGHeffect	-	-	-
	InfoToxicity	-	-	-
	InfoPlace	-	-	-
	InfoUse	-	-	-
Provided InfoB	InfoB	-	-	-
	InfoNyos	-	-	-
	InfoHotSpring	0.089 *	0.149 **	-
	InfoPaintfactory	-	-	-
	InfoDome	-	-	-
	InfoMtMammoth	-0.113 **	-0.176 **	-
Provided InfoC	InfoC	-	-	*(MC)*

	InfoCapture	*(MC)*	*(MC)*	*(MC)*
	InfoTransport	*(MC)*	*(MC)*	*(MC)*
	InfoCauseEarthquake	-0.067 **	*(MC)*	-0.066 **
	InfoLiquidLike	*(MC)*	-	*(MC)*
	InfoUnderground	*(MC)*	-	*(MC)*
	InfoLeakSoil	*(MC)*	-0.079 **	*(MC)*
	InfoLeakCracks	-	-	-
Provided InfoD	InfoCO_2andCCS	0.057 *	-	-
	InfoWhatCCS	-	-	0.074 **
	InfoExtraEnergy	-	-	-
CCS Consequence (order effects)		-0.060 **	-0.050 **	-0.072 **
CO_2 impression2	CO_2Positive2	-	0.066 **	0.068 **
	CO_2Clean2	0.042 *	-	-
	CO_2Useful2	-	-	-
	CO_2Dangerous2	0.059 **	0.095 **	0.062 **
CCS consequence likelihood	MoveAtmosphere	-	-	-0.064 **
	Soil	-	-0.073 **	-0.091 **
	LeakOn	-	-	-
	LeakOff	-	-	-0.069 **
	FlowIntoSea	-0.060 **	-	-
	EarthquakeLeak	-	-0.062 **	-
CCS consequence misperception	ChemicalReact	-	0.038 *	-
	Caprock	-	-	-
	Fire	-	-	-
	Ecosystem	-	-	-
	Vacant	-	-	-
	Radiation	-	-	-
	Solid	-	-	-
CCS perception and opinion	MeasureMonitor	0.080 **	0.071 **	0.044 *
	BreakDown	-0.058 **	-	-
	ManyRisk	-0.294 **	-0.223 **	-0.196 **
	Gurantee	-	-0.056 **	-
	MitigateCC	0.293 **	0.197 **	0.238 **
	KnowEnough	0.103 **	0.075 **	0.091 **
	WhatHappen	-	-0.082 **	-
Trustworthy source	NationalGov	0.057 **	-	0.066 **
	LocalGov	-	-	-
	NationalTV	-	-	-
	NationalPaper	-	-	-
	LocalPaper	-	-	-
	Scientist	-	-	-
	Developer	0.039 *	0.052 **	0.037 *
	NationalNGO	-	-	-
	LocalNGO	-	-	-
	Friend	-	-	-
	Website	-	-	-
	UNagency	-	0.045 *	-
CO_2 related activity	Activity	-	0.035 *	-
Information	Nature	-	-	-

gathering topics	Environment	-	-	-0.065 **
	Physics	-	-	-
	News	-	-	-
	Technology	-	-	-
	Biology	-	-	-
	Science	-	-	-
Demographics	Univ_dmy	-	-	-
	Female_dmy	-	-0.069 **	-
	U20s_dmy	-	-	-
	a30s_dmy	-	-	-
	a40s_dmy	-	-	-
	a50s_dmy	-	-	-
	O60s_dmy	-	-	-
	Csea_dmy	-	-	-
Country	CountryJP	-	-	-0.165 **
	CountryNL	-0.058 **	-	-
Adjusted R-squared		**0.440**	**0.361**	0.424

Note) *: significant level below 5%, **: significant level below 1%
(MC): the covariate is excluded from the regression analysis because of high multicollinearity with other covariate (VIF is higher than 10)

For this table, the adjusted R-squared (0.361– 0.440) indicates that the regressions reasonably explain the factors of overall opinion formation on CCS implementations to an extent. It was found that 'DoForGW' and 'MoreTax' correlated with 'no opinion change' negatively in the value and belief category. Conflating the effects of CO_2 with those of CO, and misperceptions of CCS such as 'FlowIntoSea' and 'Vacant', were also correlated with 'no opinion change' negatively. Further, 'no opinion change' participants tended to have knowledge of the uses of CO_2 (i.e. 'Fire Extinguisher'), less trust in scientists as a source of information ('Scientist'), and were more involved with CO_2 related activities ('Activity').

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